



4.0 SELECTION OF THE RECOMMENDED CORRECTIVE MEASURE

4.1 Comparison of Alternatives

The risk assessment and groundwater model performed as part of the RFI demonstrated that no risk exists with current site conditions. The evaluation of corrective action alternatives in Section 3.0 indicated that establishment of a groundwater monitoring program in conjunction with the modifications to engineering practices and equipment design to prohibit future releases in both areas would meet the objectives of the CMS. In addition, although the risk assessment indicated no risk, several corrective action options would shorten the time for monitoring site conditions to confirm the model and risk assessment. After evaluating all criteria presented in Section 3.0, four options were determined to most effectively meet the site objectives. These options, which apply to the tankfield and railroad siding area, include the following:

1. Establishment of a groundwater monitoring program.
2. Establishment of a monitoring program AND soil removal in the tankfield area.
3. Soil removal in the tankfield area AND high-vacuum total phase extraction in the railroad siding area.
4. Pump-and-treat and soil vapor extraction, conducted simultaneously in both affected areas (the feasibility of this alternative assumes that heavily-impacted soils will be removed during already-planned UST excavation and removal).

All options include modifications to engineering practices and equipment design to prohibit future releases in both areas. Quebecor is committed to instituting these engineering changes and has already completed most of them. All options include a groundwater monitoring program, although the scope of the monitoring program is specifically tailored to each option.

A study by Wilson and Brown¹ indicated that for a typical hydrocarbon spill (specifically gasoline) less than 5 percent of the contaminant mass is dissolved in the groundwater. This suggests that soil remediation will address the bulk



of a release to soil and groundwater. At the Quebecor facility, the groundwater model has shown the groundwater plume to be stationary due to a balance of groundwater migration and natural biodegradation rates with current conditions. Therefore, remediation of the affected soil will address the major mass component of the chemicals of concern and thereby reduce the time that may be deemed necessary to monitor site conditions.

These four options are conceptually considered to be capable of achieving the goal of corrective measures at the site: protection of human health and the environment surrounding the facility relative to chemicals of concern (CoCs) at the site. Options 2 through 4 are presented to reduce the time frame for monitoring under option 1. Variations between options are discussed in the following paragraphs.

Option 1: Engineering practices and equipment design to prohibit future releases in both areas AND establishment of a groundwater monitoring program

Quebecor has instituted extensive changes in the handling, storage, and operation of the solvent system and its handling, storage, and disposal of hazardous materials in the tankfield area. These changes include, but are not limited to, the following:

- installation of all aboveground solvent transfer lines from the underground storage tank field (November 1993)
- removal of the underground fuel oil tank (Spring 1994)
- replacement of the aboveground fuel oil storage tank (Spring 1994)
- construction of an environmentally-safe bulk ink and solvent loading and off-loading pad (Spring - Summer 1994)
- construction of aboveground solvent storage tanks (Spring - Summer 1994)
- removal of all underground solvent storage tanks (scheduled for September 1994).



Each of the changes will help ensure that the present "no risk" circumstances at the facility are maintained.

The majority of the system changes have already been completed. In combination, they eliminate the potential for undetected subsurface releases and provide for immediate containment and cleanup should any aboveground release occur. Engineering specifications for the aboveground storage tank system are attached in Appendix E.

In the railroad siding area, engineering practices and system modifications were instituted in 1988 - 1989, in response to the surface solvent release of November 1988. These measures, which were instituted to prevent reoccurrence of a similar event, were documented in the incident report submitted to the PADER (included in the USEPA Administrative Record). These measures have been effective and no releases have occurred in this area in the past six years.

This option would also establish a groundwater monitoring program in both areas to monitor the stability of impacted groundwater which has been predicted to be immobile and unrelated to any exposure pathways. This program would include quarterly sampling of perimeter network wells in each area. A perimeter network consists of a selected number of monitoring points located proximal to and downgradient of the affected areas. The detection of any solvent-indicator compound above analytical detection limits in a perimeter well, and confirmed by resampling the well, will result in the re-assessment of the perimeter network program. Site conditions will be reevaluated relative to the risk assessment and groundwater model, and recommendations for further action presented, if necessary.

Option 1 presents a monitoring program which includes quarterly sampling of perimeter network wells, annual sampling of all onsite groundwater monitoring wells, and annual sampling of downgradient domestic wells. Samples will be analyzed for solvent-indicator compounds.



This option meets the CMS objective, generates no waste material, monitors the effectiveness of natural biodegradation, and confirms the results of the groundwater modeling exercise, which indicated no offsite migration of CoCs.

Option 2: Engineering practices and equipment design to prohibit future releases in both areas AND establishment of a monitoring program AND soil removal in the tankfield area

This option includes modifications to engineering practices and equipment design to prohibit future releases in both areas as described in option 1. These changes will help ensure that the present "no risk" circumstances at the facility are maintained. Moreover, the groundwater monitoring program specifications will be the same as in option 1.

This corrective measure option provides the same benefits as option 1 for the railroad siding area, since it establishes the same groundwater monitoring program. However, this option would go a step further in the tankfield area and remove unsaturated soils affected at levels above risk based limits as determined during UST removal. This option would thus reduce potential source areas. However, excavation would generate substantial volumes of soil that would have to be disposed of as hazardous waste. Transportation of these hazardous wastes offsite could present some additional risk to the environment and community.

This option meets the CMS objective by maintaining the current "no risk" conditions at the facility, removes the affected soil in the tankfield area, and monitors the effectiveness of natural biodegradation in the railroad siding area. Soil excavation may generate a significant volume of waste; however, it will be on a one-time basis and will substantially improve soil quality in that area.

PERMETER wells

YGLY

ALL DOWNGRADIENT DOMESTIC-DIMMALLY
wells

3, 4,
89
10, 12
13
K1
R2
SA
ED
E



Option 3: Engineering practices and equipment design to prohibit future releases in both areas AND soil removal in the tankfield area AND high-vacuum total phase extraction in the railroad siding area

This option includes the same changes discussed in option 1 that will help ensure that the present "no risk" circumstances at the facility are maintained. This option also combines all of the beneficial features of option 2 with high-vacuum total phase extraction in the railroad siding area. This option is thus even more protective of the "no risk" circumstances than option 2.

The groundwater monitoring program for option 3 includes quarterly sampling of perimeter network wells in the tankfield and railroad siding area. The confirmed detection of any solvent-indicator compound in these wells will result in the re-assessment of the recommended corrective action approach.

The groundwater monitoring program for option 3 will also include annual sampling of downgradient domestic supply wells for continued confirmation of the risk assessment. (?) YqLY

The railroad siding area would be addressed by high-vacuum total phase extraction. This option would shorten the monitoring period for the railroad area by further reducing the CoCs in soil and groundwater. This system aggressively remediates soil impact while simultaneously increasing water yield for treatment (through vacuum application) and lowering the water table (by dewatering). As the water table is lowered, a larger volume of soil becomes available for vapor extraction.

This option meets the CMS objective by maintaining the current "no risk" conditions at the facility, removes the affected soil in the tankfield area, and remediates the affected soil and groundwater in the railroad siding area. Soil excavation will generate a significant volume of waste; however, it will be on a one-time basis and will substantially improve soil quality in that area. Waste generation volumes from the high-vacuum total phase extraction system in



the railroad siding area would be limited to spent air stripper tower packing material, and spent carbon used to polish effluent water from the air stripper and to treat effluent air. This option would be most effective in achieving beneficial results quickly.

Option 4: Engineering practices and equipment design to prohibit future releases in both areas AND pump-and-treat with soil vapor extraction in both the tankfield and railroad siding area

This option includes modifications to engineering practices and equipment design to prohibit future releases in both areas as described in option 1. The groundwater monitoring program is the same as in option 3.

This option addresses soil remediation in both the tankfield and railroad area; however, it does not address soil in the tankfield area as expeditiously as in option 3. Soils of this type, clay-rich with low permeability, can be more effectively addressed by removal than remediation, and thus option 3 is preferred.

This options meets the CMS objective by maintaining the current "no risk" conditions at the facility, generates a smaller volume of waste than option 3, and ranked second in terms of the time needed to achieve beneficial results.

4.2 Recommendation of Corrective Measure

Of the four alternatives presented above, option 3 (modifications in engineering practices and equipment design in both areas, soil removal in the tankfield area, and high-vacuum total phase extraction in the railroad siding area) would be the most effective at meeting the goals of corrective measures at the site. This conclusion is based on the fact that this option protects human health, prohibits future releases, removes affected soils in the tankfield area, and remediates soils in the railroad area, in a reasonable amount of time and with reasonable waste generation for both areas.

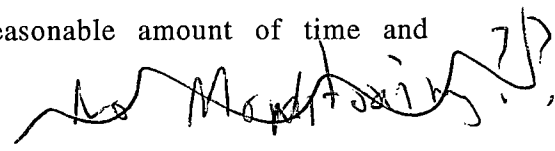
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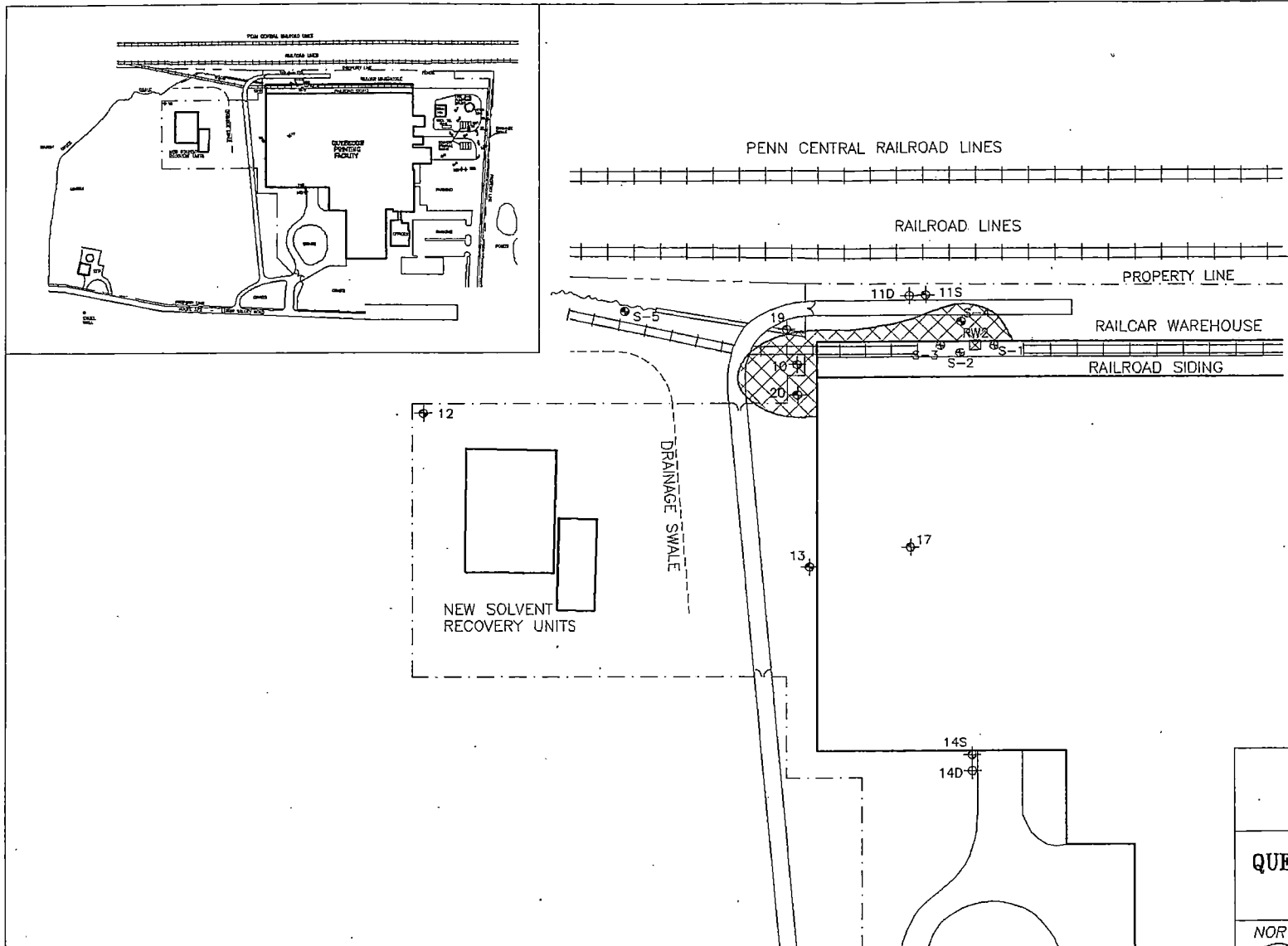
TABLE 3-1
SUMMARY OF REMEDIAL ALTERNATIVES
TANKFIELD AREA
QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	TREATED MEDIUM	RELATIVE EFFECTIVENESS	RELATIVE TIME LINE	RELATIVE COST	RELATIVE FEASIBILITY	TECHNICAL EVALUATION CRITERIA PASS/FAIL	SITE SPECIFIC APPLICABILITY PASS/FAIL	COMBINED CRITERIA PASS/FAIL
IN SITU TREATMENT								
NO ACTION	None	Low	Long	Low	Low	Fail	Pass	Fail
SITE MONITORING	None	Low	Long	Low	Low	Pass	Pass	Pass
PUMP & TREAT	Groundwater; some soil	Moderate	Long	Moderate	High	Fail	Pass*	Fail
VAPOR EXTRACTION	Soil; some groundwater	Moderate	Short	Low	Moderate	Fail	Pass*	Fail
BIOREMEDIATION	Soil and groundwater	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
AIR SPARGING	Groundwater and soil	Moderate	Short	Moderate	Moderate	Fail	Fail	Fail
BIOLOGIC ENHANCEMENT BY SOIL VENTING	Groundwater and soil	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
EX SITU, ON-SITE								
INCINERATION	Soil only	High	Short	High	Low	Fail	Fail	Fail
ABOVE GROUND BIOREMEDIATION	Soil only	Moderate	Moderate	Moderate	Moderate	Fail	Fail	Fail
EX SITU, OFF-SITE								
DISPOSAL AND LANDFILLING OR INCINERATION	Soil only	High	Short	High	Low	Pass	Pass	Pass
COMBINED ALTERNATIVES								
PUMP & TREAT/ SOIL VAPOR EXTRACTION	Groundwater and soil	High	Moderate	Moderate	High	Pass	Pass	Pass
PUMP & TREAT/ SOIL DISPOSAL	Groundwater and soil	Moderate	Moderate	Moderate	High	Fail	Pass	Fail
VAPOR EXTRACTION & BIOREMEDIATION	Groundwater and soil	High	Moderate	Moderate	Moderate	Pass	Fail	Fail

* = Only fully applicable if used as an element of a combined remedial plan

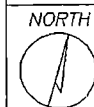
LEGEND

- ⊕ MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ DEEP MONITORING WELL
- ⊠ AREA OF IMPACT



AREA OF IMPACT AT THE
RAILROAD SIDING

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA



SCALE IN FEET

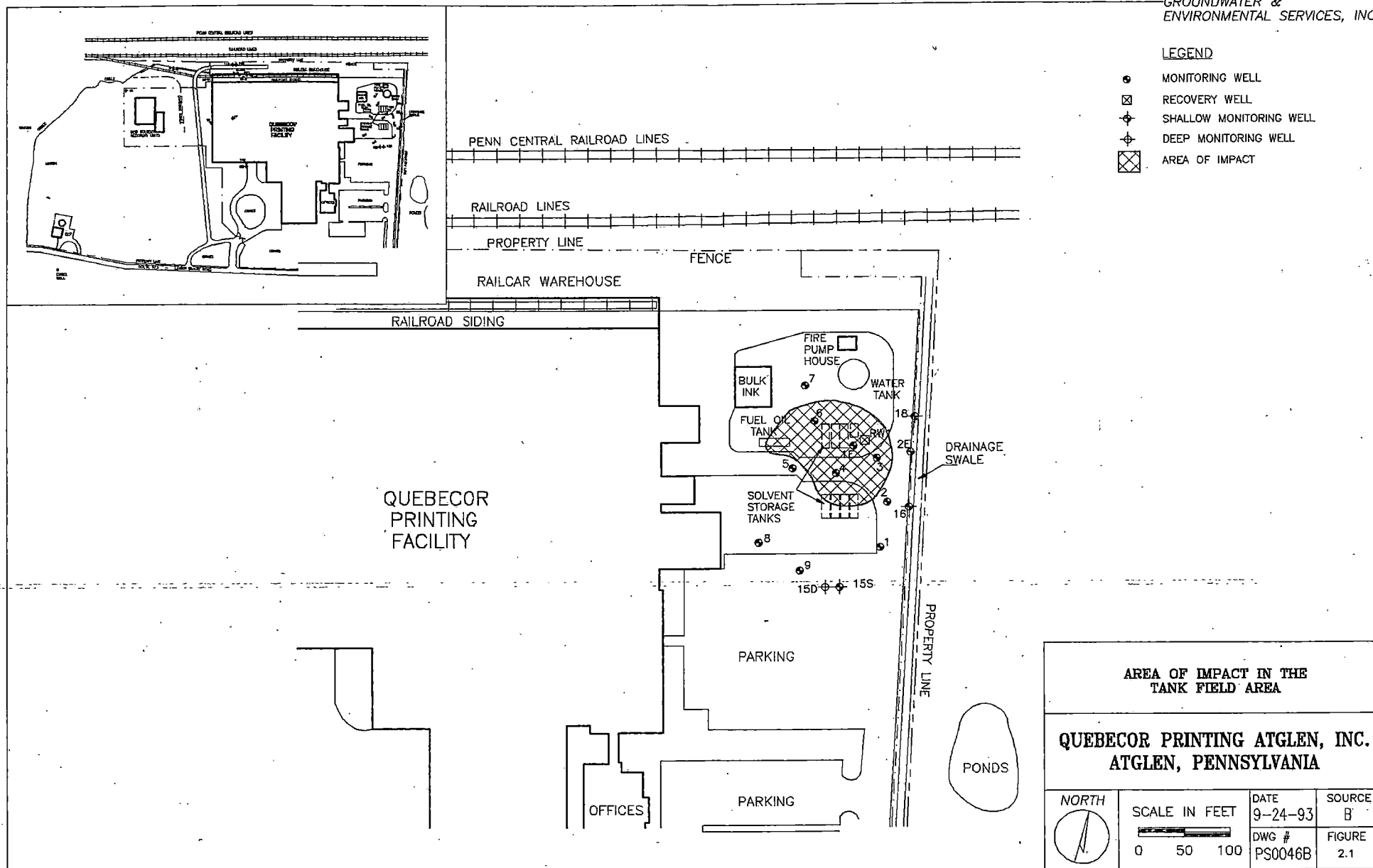
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SOURCE
B
FIGURE
2.2

LEGEND

- MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ DEEP MONITORING WELL
- ⊠ AREA OF IMPACT



**AREA OF IMPACT IN THE
TANK FIELD AREA**

**QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA**

<p>NORTH</p>	<p>SCALE IN FEET</p>	DATE	SOURCE
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		DWG #	FIGURE
		PS0046B	2.1

TABLE 3-2
SUMMARY OF REMEDIAL ALTERNATIVES
RAILROAD SIDING AREA
QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	TREATED MEDIUM	RELATIVE EFFECTIVENESS	RELATIVE TIME LINE	RELATIVE COST	RELATIVE FEASIBILITY	TECHNICAL EVALUATION CRITERIA PASS/FAIL	SITE SPECIFIC APPLICABILITY PASS/FAIL	COMBINED CRITERIA PASS/FAIL
IN SITU TREATMENT								
NO ACTION	None	Low	Long	Low	Low	Fail	Pass	Fail
SITE MONITORING	None	Low	Long	Low	Low	Pass	Pass	Pass
PUMP & TREAT	Groundwater; some soil	Moderate	Long	Moderate	High	Fail	Fail	Fail
VAPOR EXTRACTION	Soil; some groundwater	Moderate	Short	Low	Moderate	Fail	Pass*	Fail
BIOREMEDIATION	Soil and groundwater	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
AIR SPARGING	Groundwater and soil	Moderate	Short	Moderate	Moderate	Fail	Fail	Fail
BIOLOGIC ENHANCEMENT BY SOIL VENTING	Groundwater and soil	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
EX SITU, ON-SITE								
INCINERATION	Soil only	High	Short	High	Low	Fail	Fail	Fail
ABOVE GROUND BIOREMEDIATION	Soil only	Moderate	Moderate	Moderate	Moderate	Fail	Fail	Fail
EX SITU, OFF-SITE								
DISPOSAL AND LANDFILLING OR INCINERATION	Soil only	High	Short	High	Low	Fail	Fail	Fail
COMBINED ALTERNATIVES								
PUMP & TREAT/ SOIL VAPOR EXTRACTION	Groundwater and soil	High	Moderate	Moderate	High	Pass	Pass	Pass
PUMP & TREAT/ SOIL DISPOSAL	Groundwater and soil	Moderate	Moderate	Moderate	High	Pass	Fail	Fail
VAPOR EXTRACTION & BIOREMEDIATION	Groundwater and soil	High	Moderate	Moderate	Moderate	Pass	Fail	Fail

* = Only fully applicable if used as an element of a combined remedial plan



4.3 Proposed Remedial System

4.3.1 Remedial System Overview

Tankfield Area

For the tank field area, the remedial option being recommended is soil removal. This option achieves the CMS objectives at the tank field area because (1), soil impacted by CoCs will be removed; (2) all underground storage tanks, which may be a source of CoCs will be removed; (3) no new underground storage tanks or buried piping runs will be reinstalled in the vicinity of the tank field, greatly reducing the chance for additional subsurface releases; (3) the groundwater model completed for the tankfield area shows that no offsite migration of chemicals of concern will occur; (4) and, the risk assessment completed for the site shows that there is no risk associated with chemicals of concern in this area.

Railroad Siding Area

Field testing and all data gathered throughout this CMS indicates that, if active remediation is to be conducted at the railroad siding, high-vacuum total phase extraction is the most effective and efficient option to be used. This option will remediate both soils and groundwater in that area.

SVE

With this remediation strategy a vacuum tube is installed in each vapor point, to a depth below the static water table. When vacuum is applied, water is evacuated from the well and pumped to a treatment facility to eliminate upwelling or mounding caused by induced vacuum. As the groundwater is withdrawn to a level below the tube, the same vacuum line is used to vent soils. As additional groundwater is removed by the system, the water table is depressed, creating a larger volume of unsaturated soil that can be treated effectively by the vapor extraction system. The vacuum applied to these points will artificially increase the withdrawal of water, thus increasing the rate that



the water table can be depressed, and maximizing the amount of groundwater treated.

Finally, air turnover in the subsurface will add oxygen, which promotes the natural degradation of VOCs by aerobic bacteria. Bioremediation testing conducted at the site indicated that sufficient native bacteria exists in the soils to degrade hydrocarbon compounds. The field testing also suggests that natural biodegradation of affected soils will increase when the amount of available oxygen is increased. Therefore, high-vacuum total phase extraction will further enhance natural degradation of VOCs by aerobic bacteria by providing oxygen through air turnover in the subsurface. ~~☆~~ ~~☆~~

4.3.2 Proposed Remedial System Design

Tankfield Area:

As noted in Section 3.3 of the CMS, the existing USTs and associated piping runs will be removed first, prior to the initiation of any full scale remediation program.

When approval is granted by all applicable agencies, Quebecor would begin a soil excavation program which would entail the removal of all significantly impacted soil in the area located above the static water table. This program would begin by removing clean surface soil (defined for the purpose of this report as any soil with a field-scanned organic vapor monitor [OVM] reading of 10 units or less), and would be stockpiled for reuse. All soils with an OVM reading of greater than 10 units would be stockpiled for disposal.

From data collected during the RFI and CMS studies, it is anticipated that the uppermost two to five feet of soil will be considered clean, and stockpiled. In impacted areas, soils down to a depth of approximately 12 feet would then be removed and stockpiled separately. Soils deeper than 12 feet would not be removed since they would have too high a liquid content to be disposed of 12 ft



without additional mixing with a drying agent. The anticipated areal extent of soil removal is shown in Figure 4-1.

All impacted, stockpiled soils would be placed on plastic sheeting. At the completion of each stockpile, the soil would be covered with additional plastic sheeting, and would be securely anchored. All stockpiled soil would be sampled, per all applicable requirements, manifested, and disposed of at an approved offsite disposal facility. Quebecor would remove all stockpiled soils from the site within 90 days of generation.

Any material needed to fill in excavated material would be composed of borrow-material, graded from areas surrounding the facility. The fill material used would be of a similar soil type as the native soil from this facility.

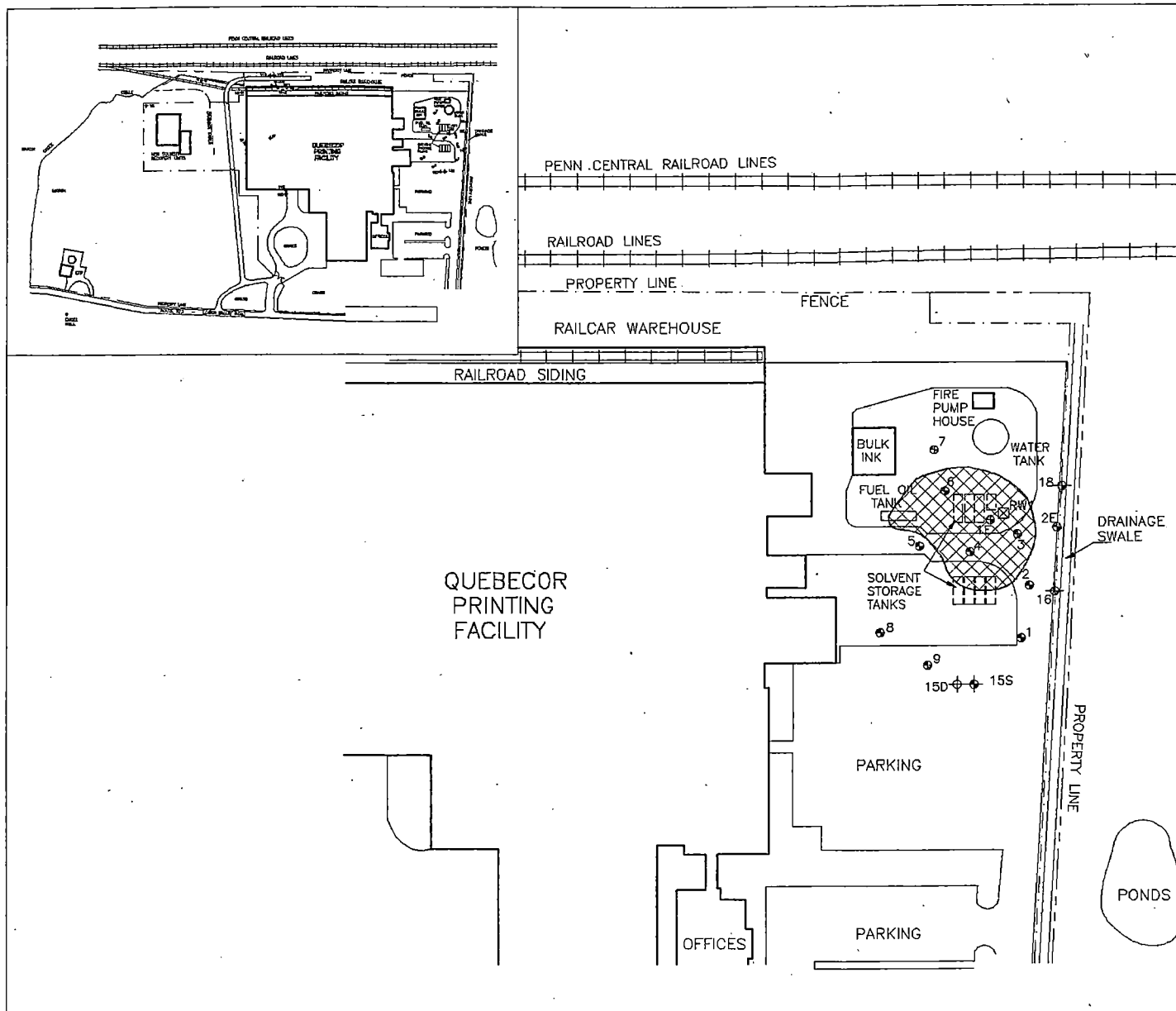
Railroad Siding Area:

The remediation system proposed for this area would consist of approximately 24 soil vapor extraction points manifolded in eight legs of three extraction points each (Figure 4-2). The vapor extraction points would be constructed of 4-inch diameter, 0.040-inch slotted PVC well screen joined to PVC riser (Figure 4-2). A below-grade pitless adapter would be installed near the top of each extraction point so the well can be tied into a manifold system. The vapor extraction points will be installed with a truck-mounted hollow-stem auger drill rig, and will be installed to a depth of approximately 15 feet.

Each extraction point would be capable of removing vapors and water as it accumulates in the well. This process would be controlled by sensors in the well that would open and close solenoid valves as shown on Figure 4-3.

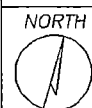
LEGEND

- ⊙ MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊖ DEEP MONITORING WELL
- ⊞ AREA OF IMPACT



AREA OF IMPACT IN THE
TANK FIELD AREA

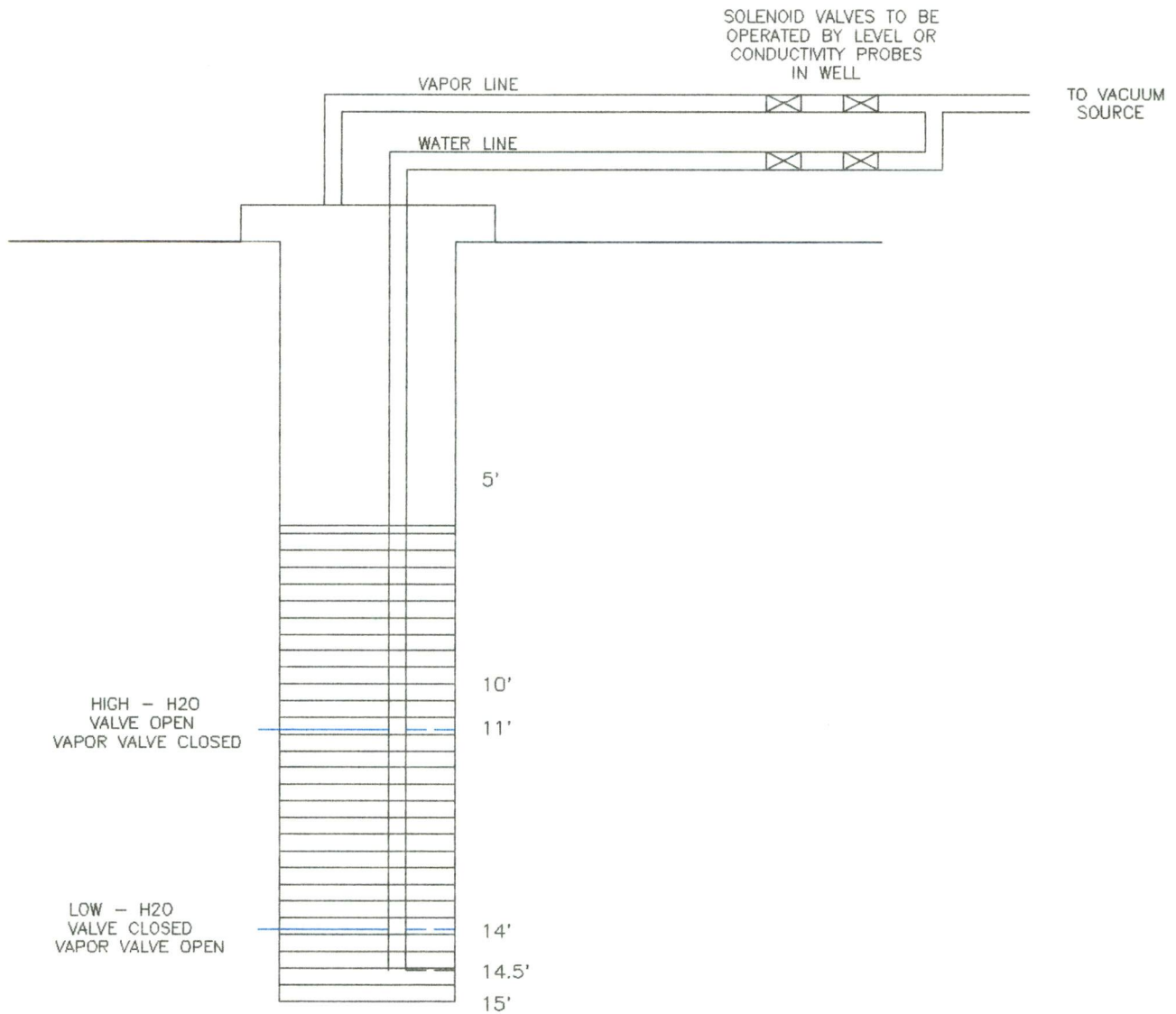
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ATGLEN, PENNSYLVANIA




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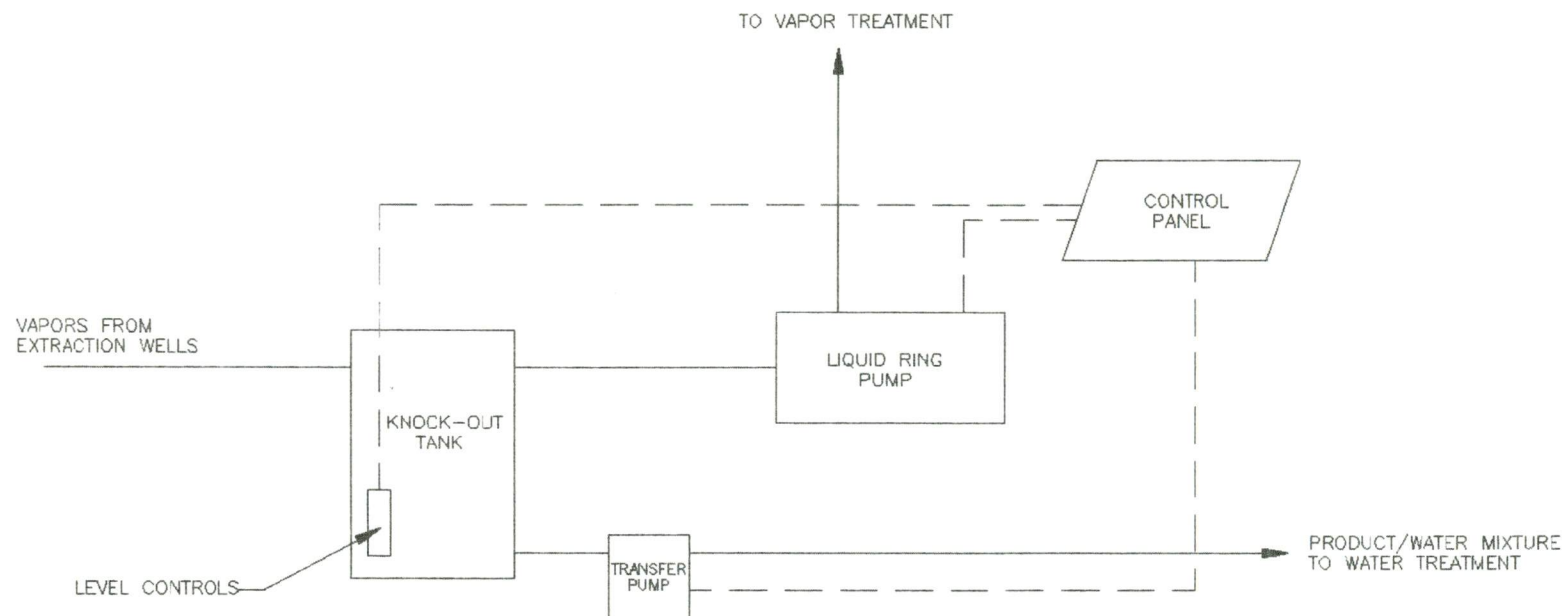
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SOURCE
B
FIGURE
4-1




**TYPICAL VAPOR EXTRACTION WELL
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA**

NORTH	DATE: 30JUNE94	CK: SR	APPV: RD
	BY: MLB	REV:	
NA	NOT TO SCALE		
	0 000		

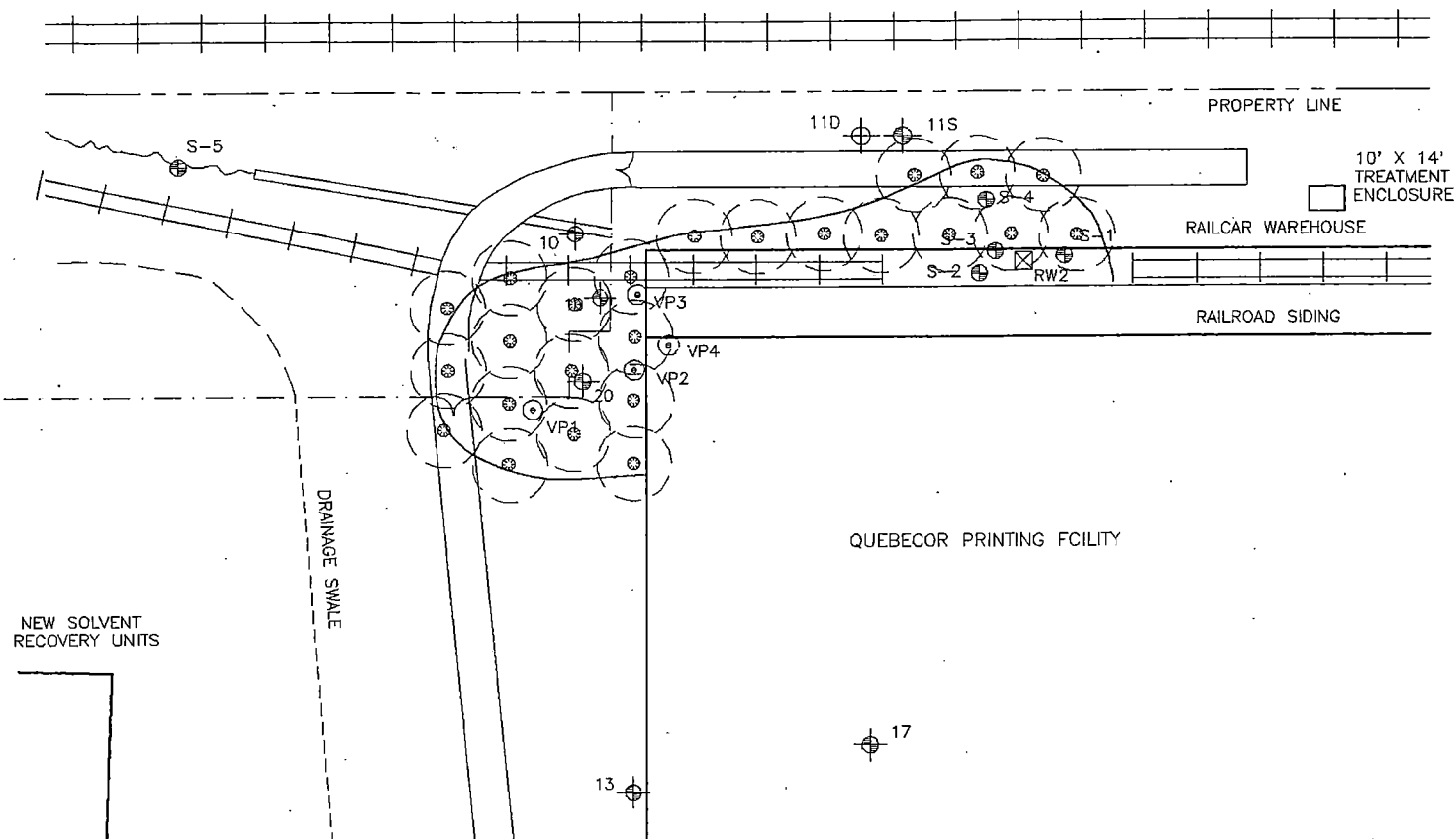


**FLOW DIAGRAM FOR VAPOR EXTRACTION
TYPICAL**

**QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA**

NORTH NA	DATE: 6JULY94	CK: SR	APPV: RD
	BY: MLB	REV:	
	NOT TO SCALE  0 1000	4-4	

PENN CENTRAL RAILROAD LINES



LEGEND

- MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ NEW SHALLOW MONITORING WELL
- ⊕ NEW DEEP MONITORING WELL
- VAPOR POINT
- AREA OF CONTAMINATION
- ⊗ VAPOR EXTRACTION WELL
- ZONE OF INFLUENCE

SVE WELL INFLUENCE

**QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA**

NORTH ↑	DATE:	CK: SR	APPV: RD
	BY: MLB	REV:	
	SCALE IN FEET 0 50	4-2	



A flow diagram for recovered water and vapors is presented on Figure 4-4 and 4-5. The off-gas from the air stripper, along with vapors from the extraction wells, will be treated by the most feasible means depending on concentrations. Treatment options include granular activated carbon, thermal destruction, or catalytic oxidation. 7.

A high-vacuum liquid ring pump would be used to create the vacuum at the vapor extraction points in the railroad siding area. Any water removed from the wells would be pumped to and processed through the water treatment system.

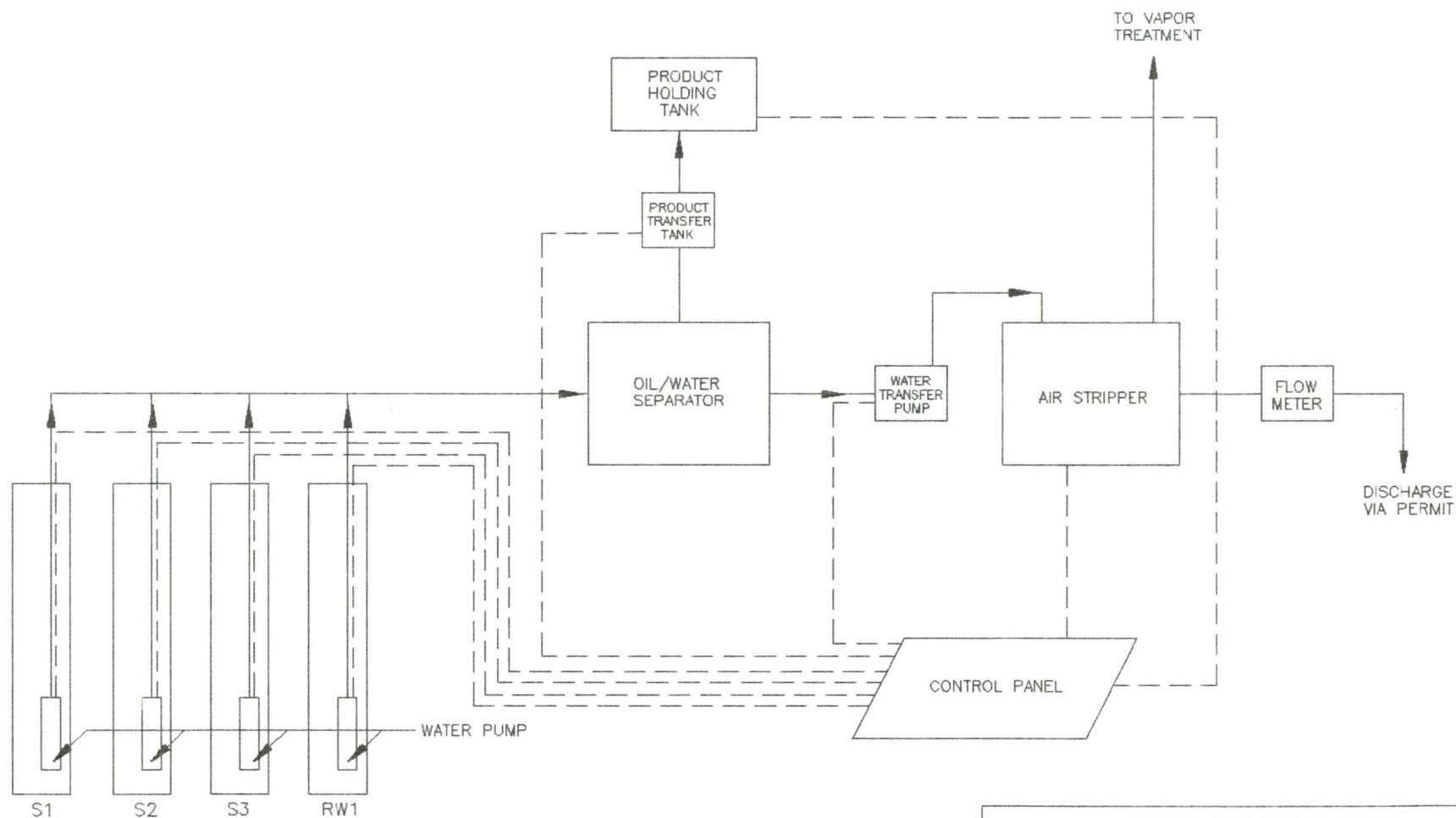
Initially, soil vapors will be withdrawn at high concentrations; these vapors would be treated with a portable thermal destruction unit. The VOC concentrations, lower explosive limits, and the oxygen content of extracted vapors would be monitored during the operation of this system to determine when it would be more cost-effective to switch to a different form of vapor treatment unit, such as catalytic oxidation or granular activated carbon.

All manifold switching equipment, a water knock-out tank, a control panel, a liquid ring pump, and a transfer pump would be located within a 10-foot by 14-foot enclosure, proposed to be installed east of existing wells S-1 and S-4.

4.3.3 Remediation Timeline


Tankfield Area:

Soil removal from the tankfield area is anticipated to take approximately two to four weeks. In addition, Quebecor will initiate a monitoring program designed to monitor groundwater quality and potential plume migration. This monitoring program is outlined in Section 4.3.4.



**FLOW DIAGRAM FOR
GROUNDWATER TREATMENT**

**QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA**

NORTH NA	DATE: 6JULY94	CK: SR	APPV: RD
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Railroad Siding Area:

The results of field work have determined that high-vacuum total phase extraction will be effective in further reducing the CoCs in the railroad siding area. Groundwater modeling has shown that no plume migration will occur, and no threat to human health and the environment is present; this system will be installed to remove residual contamination with the overall goal of reducing the required monitoring time.

Quebecor will operate a system which will effectively reduce impact from this area by remediating the soil; however, a component of the proposed high-vacuum total phase extraction system is the recovery of groundwater. Research at numerous sites has recently been completed which finds that complete restoration of groundwater through pump-and-treat techniques is frequently not possible, and may not be an environmentally sound policy once effluent concentration levels have stabilized. More specific research² has shown that concentrations of volatile organics frequently will reach an asymptotic equilibrium; continued pumping often has no further or notable effect on these concentrations, even after years of additional treatment. To avoid this problem, Quebecor will employ cutoff criteria which will be used to determine the termination of remediation. These criteria will be as follows:

- An asymptote will be considered achieved, denoting the completion of remediation, if the standard deviation from one year of groundwater monitoring data does not vary by more than 20% and does not exceed 5 parts per million per sample during the quarter; or, ?
- remediation will be considered achieved if not more than 0.50 pounds of VOCs are recovered per 10,000 gallons of groundwater pumped; or, X
- remediation will be considered completed if the average VOC concentrations in influent water for six consecutive months show a 90% or X

VST FIELD

MW-4, 8, 16, 15D - ~~ALLY~~
Gallagher _____ Annually

RASA

MW 10	_____	ANNUALLY
12	_____	ANNUALLY
14D	_____	ANNUALLY

ENGLE	_____	ANNUALLY
GALLAGHER	_____	ANNUALLY

AIR STRIPES EFFICIENT - MPDES

AIR STRIPES AIR DISCHARGE



greater reduction in concentration over the average of the first six months of operation; or,

- remediation will be considered completed even if none of the foregoing are satisfied, if Quebecor and the USEPA subsequently agree to another criteria.



4.3.4 Monitoring Program

The following monitoring program is also proposed to verify the "no risk" conditions at the facility:

Tankfield Area

- Monitor well MW-4 annually to gauge improvements in groundwater quality.
- Monitor wells MW-8, MW-16, and MW-15D (part of the perimeter monitoring network) annually to document plume immobility.
- Monitor downgradient domestic well (Gallagher) annually for confirmation of risk assessment.

Railroad Siding Area

- Monitor well MW-10 annually to gauge improvements in groundwater quality.
- Monitor wells MW-12 and MW-14D (part of the perimeter monitoring network) annually to document plume immobility.
- Monitor downgradient domestic well (Engel) annually for confirmation of risk assessment.



- Monitor air stripper influent and effluent waters for parameters dictated by the NPDES permit which would be necessary to operate a treatment system.
- Monitor air stripper and vapor system off-gas concentrations for parameters dictated by the air permit which would be needed to operate a system.
- Re-evaluate soil vapor extraction influent data after levels of VOCs stabilized or dropped below laboratory detection limits. If these data show that VOC levels reach an asymptotic equilibrium (i.e., standard deviation from one year of monitoring data does not vary by more than 20%) or were below laboratory detection limits, approval to discontinue use of the vapor system would be requested from USEPA.
- remediation will be considered completed even if none of the foregoing are satisfied, if Quebecor and the USEPA subsequently agree to another criteria.

4.3.5 Estimated Cost

A cost breakdown for this option is shown in Table 4-1.

¹ Wilson, S.B., and Brown, R.A., 1989, In Situ Bioreclamation: A Cost-Effective Technology to Remediate Subsurface Organic Contamination; Groundwater Monitoring Review, Winter 1989, pp. 173-179.

² Reaching Contaminant Concentration Asymptote Higher Than Cleanup Goals: Criteria Considerations For Discontinuing Pump and Treat at Three CERCLA Sites; Makdisi, R.S. and Garvason, R.; 1992.

TABLE 4-1
SUMMARY COST ESTIMATE FOR REMEDIATION
QUEBECOR PRINTING ATGLEN INC.

The following estimate details costs for removing impacted soil in the tankfield and initiating a remediation system in the railroad siding area:

Tankfield Area

Assumes removal of 500 cubic yards of soil, disposal as hazardous waste, and backfilling the area with clean fill. Includes establishment of monitoring program as detailed in Section 4.

Total Cost \$ 325,000

Railroad Siding Area

Capital Costs Direct

-Equipment	
-Liquid Ring Pump	\$ 16,500
20 hp, 3 phase	
-Controls	\$ 9,000
-Transfer tanks	\$ 3,000
-2 Carbon Vessels (Off Gas Treatment)	\$ 9,000
-Treatment Enclosure	\$ 7,000
-Air Stripper	\$ 7,000
-Oil Water Separator	\$ 4,500
-All Other Misc. Materials	<u>\$ 13,250</u>
-Subtotal	\$ 69,250
-Construction	
-Installation Labor	\$ 23,000
-Subcontractors	<u>\$ 42,660</u>
-Excavator	
-Electrician	
-Plumbing	
-Subtotal	\$ 65,660

Capital Costs Indirect

-Engineering	\$ 4,900
-License and Permits	\$ 2,000
-Start Up	\$ 2,830
-Building and Services	\$ 5,000
-20% Contingency	<u>\$ 26,980</u>
-Sub Total	\$ 41,710

Capital Costs Total \$ 176,620

TABLE 4-1
SUMMARY COST ESTIMATE FOR REMEDIATION
QUEBECOR PRINTING ATGLEN INC.
(Continued)

Annual O&M Costs

Operation and Maintenance (all costs are per year)

-Operating Labor Per Year Including Monitoring Program	\$ 16,500
-Maintenance Materials (replacement carbon)	\$ 7,500
-Energy	\$ 5,000
-Laboratory Fees	\$ 2,000
-Disposal Costs (Carbon)	\$ 7,500
-Administrative Costs	\$ 1,000
-Insurance, Taxes	\$ 1,000
-20% Contingency	<u>\$ 7,500</u>

Total O&M per year **\$ 48,000**

APPENDIX C

BIOREMEDIATION ASSESSMENT OF THE QUEBECOR PRINTING ATGLEN SITE



1.0 INTRODUCTION

The following document discusses the field and laboratory testing that was performed to evaluate the use of bioremediation techniques for the remediation of hydrocarbon contamination at the site. In order to evaluate whether the implementation of bioremediation is appropriate, an evaluation of current site conditions relative to microbiological activity was made. The purpose of performing this initial evaluation was to establish baseline levels and to evaluate whether onsite conditions can be optimized to promote bioremediation. Based on the information currently available, the following phased approach for implementing bioremediation at the site is being considered:

- Use of high vacuum extraction to maximize hydrocarbon contaminant volatilization and free product recovery;
- Operation of vapor extraction system to promote bioventing;
- Monitoring of natural bioremediation for the remediation of any remaining residual contamination.

The collected data will be evaluated to assess the feasibility of the phased approach.

2.0 METHODOLOGIES

In order to efficiently evaluate the feasibility of implementing bioremediation at the site, the following characterization studies were performed:



2.1 Bioremediation Characterization of Groundwater and Soil

Based on the historical data available, groundwater and soil samples were obtained from regions at two designated areas (tankfield and railroad siding) of the site which exhibited low, average and high concentrations of the hydrocarbon contaminants. Table 1 lists the analyses which were performed.

The following monitoring wells were sampled:

<u>Tankfield</u>	<u>Railroad Siding Area</u>
MW-2	S-1
MW-3	S-4
MW-15S	MW-11S

Figures 1 and 2 illustrate the groundwater and soil sampling locations. The samples were collected following GES standard sample collection and Quality Assurance/Quality Control criteria.

2.2 Soil Gas Survey

For bioventing to be successful in stimulating biodegradation, the contaminated areas must be oxygen deficient. In order to evaluate site conditions in regard to this, a soil gas survey was initially performed in the vadose zone soils in one area of interest (tankfield). The soil gas sampling locations for the tankfield are presented in Figure 3. Soil gas sampling probes were installed in the designated area at a depth of approximately 4 feet below ground surface. Parameters that were determined in the soil gas included percent O₂, percent CO₂ and percent methane.



2.3 Bioventing Assessment

Soil gas permeability is the most important site characteristic to evaluate when considering bioventing. The purpose of this evaluation was to determine if the designated areas of the site are permeable enough to allow a minimum of approximately one soil gas exchange per week. This evaluation was done in conjunction with the high vacuum extraction evaluation. Parameters that were determined in the soil gas included percent O₂, percent CO₂ and percent methane.

Initially, a soil gas sampling grid was determined in conjunction with the area designated for vapor extraction testing. Seven soil gas sampling probes were installed at a depth of approximately four feet below ground surface. The soil gas sampling locations for the tankfield are presented in Figure 3. These locations were sampled before the performance of the high vacuum extraction test; midway during the high vacuum extraction test and at selected intervals following the completion of the high vacuum extraction test. This data was evaluated to determine the rate of oxygen consumption during biodegradation of the hydrocarbon contaminants by the indigenous (native) microbial population.

3.0 RESULTS

The results of the analyses that were performed on the collected groundwater and soil samples are summarized in Tables 2 and 3.

3.1 Microbiological Enumerations

This entailed determining the total number of heterotrophic bacteria and specialized groups of bacteria: toluene degraders, xylene degraders and total petroleum hydrocarbon (TPH) degraders in collected groundwater and soil samples.



3.2 Inorganic Groundwater Analyses

Inorganic nutrient analysis (nitrogen, phosphorus, iron and sulfate) and pH were determined to assess background conditions and to evaluate whether nutrient addition or pH adjustment would be required depending on the remediation technology chosen. Iron and sulfate levels were determined to assess background conditions and to evaluate whether site conditions are conducive for natural attenuation.

3.3 Inorganic Soil Analyses

Inorganic nutrient analysis (nitrogen and phosphorus) and soil pH were determined to assess background conditions and to evaluate whether nutrient addition or pH adjustment would be required depending on the remediation technology chosen.

3.4 Organic Analysis

In the groundwater samples, the concentration of total organic carbon (TOC) and benzene, toluene, ethylbenzene and xylenes were determined. In the soil samples, the concentration of benzene, toluene, ethylbenzene and xylenes were determined. This information was used to evaluate background conditions relevant to the potential of implementing bioremediation techniques.

4.0 DISCUSSION

The following is a discussion of the results.



4.1 Microbial Enumerations

Microbial activity in the soil and groundwater was assessed by determining the number of microorganisms present in a given sample. Plate count analysis is one method of determining microbial population numbers. For this procedure, suitable sterile dilutions of the collected samples were pipetted onto petri dishes containing an agar-based growth medium. The petri dishes were then incubated at room temperature for fourteen days until microbial colonies could be visibly detected. Each microbial colony that could be visibly detected is the result of the growth of a single bacterium repeatedly reproducing under optimal growth conditions. After accounting for the dilution factor used, the minimum number of viable bacteria present in a designated sample was determined. The results are reported as colony-forming-units (cfu) per gram of dry-weight (soil) or milliliter (ml) (groundwater). Microbial enumerations from soil samples are corrected for the moisture content of the soil. This method of microbial enumeration does have limitations. There is no single type of agar growth medium that will support the growth of all types of microorganisms. For example, subsurface microorganisms may not grow on agar plates containing high levels of organic carbon such as those used to enumerate wastewater or medical microorganisms. The subsurface microorganisms may only grow when cultured on agar plates containing low levels of organic carbon similar to the concentrations found in their natural environment. Therefore, the results obtained from the plate count analysis are interpreted as the minimum instead of the actual number of viable organisms present in a soil sample.

For the samples collected at the site, plate count enumerations for total heterotrophs, toluene and xylene degraders were performed. Total heterotrophic microorganisms are defined as that group of microorganisms which obtain their energy from the oxidation-reduction reactions of organic compounds and their required carbon from organic carbon. Petroleum hydrocarbon (PHC) biodegradation is the direct result of heterotrophic metabolism where the PHCs serve as a source of carbon and energy for the microorganisms. Enumeration of the total heterotrophic population was



determined by spread plating a dilution of an aliquot of sample from each respective area (and matrix) onto a general purpose solid microbial growth medium. All spread plates were done in duplicate. The values reported represent the geometric mean of the duplicate enumerations.

Plate count techniques allow tailoring of the growth media to allow the selection of specific physiological groups of microorganisms. This tailoring allows the determination of the number of microorganisms present in a sample that are capable of metabolizing a specific contaminant of interest. Because of the nature of the hydrocarbon contaminants at this site, the enumeration of toluene and xylene degraders was performed. Enumeration of toluene and xylene degraders was performed by spreading a small sample volume onto an agar growth medium (spread plating) and incubating the plates in an atmosphere saturated with the compound of interest (i.e., toluene or xylene) as the sole source of carbon and energy. All spread plates were done in duplicate. The values reported represent the geometric mean of the duplicate enumerations.

TPH degraders were determined using the Sheen Screen technique. This is a most-probable-number technique. The most probable number (MPN) method is an alternative to plate count methods for enumerating microorganisms. The MPN method employs the use of a liquid culture media as opposed to the solid culture media utilized in the plate count method. For the Sheen Screen MPN method for determining TPH degraders, a petroleum hydrocarbon is employed as the sole carbon and energy source in the growth media. For the soil samples collected at this site, number 2 fuel oil was used as the petroleum hydrocarbon source. The MPN method utilizes statistical analysis and successive dilution (reduction in concentration) of the sample. Replicate dilutions are observed for growth or no-growth after inoculation and incubation of a particular dilution of the sample. If viable micro-organisms are present in the respective dilution of the sample that can use the number 2 fuel oil as the sole source of carbon and energy, growth will occur after the aliquot is introduced into the MPN culture medium.



The observations of growth or no-growth are scored as positive or negative respectively. The pattern of positive or negative scores are used in connection with appropriate statistical tables to obtain the most probable number of viable microorganisms present in a sample.

As summarized in Figures 4 and 5, the data indicate the presence of all categories of microorganisms at all locations sampled at the site over a wide range of toluene and xylene concentrations. This suggests an enrichment of the indigenous microbial community for populations with the metabolic capabilities to degrade toluene and xylene.

4.2 Inorganic Analyses

The most significant inorganic nutrients needed for microbial growth are nitrogen (typically in the form of ammonia) and phosphorus (typically in the form of ortho-phosphate). In general, the levels of inorganic nutrients are within acceptable ranges for bioremediation. Iron and sulfate levels were determined in the groundwater samples because there is evidence that these compound can serve as terminal electron acceptors in the absence of oxygen (anaerobic conditions) for the biodegradation of toluene and xylene. Changes in these levels would be tracked over time to monitor the potential for anaerobic degradation of the hydrocarbon contaminants at the site.

The soil pH can affect the availability and mobility of the contaminants. Soil pH can also be toxic or inhibitory to the microorganisms. The ideal pH range for most microbiological activities is in the range of 6.5 to 8.5. The pH range for the soil and groundwater samples at all locations was within this acceptable range.



4.3 Organic Analyses

Total organic carbon levels in the groundwater samples ranged from 13.65 to 143.40 parts per million (ppm). Toluene levels ranged from less than the minimum detection level (BDL) to 83,000 µg/l. Total xylenes ranged from BDL to 2,900 µg/l. These data indicate that at some locations other organic compounds (many naturally occurring) besides the hydrocarbon contaminants are present. This can have an effect on the rate of biodegradation of the hydrocarbon contaminants as the other organic compounds may be preferentially degraded first before the hydrocarbon contaminants are utilized by the indigenous microorganisms. It is also possible that the presence of the other organic compounds may also stimulate the biodegradation of the hydrocarbon contaminants. In this scenario the same metabolic capabilities that are utilized to degrade the other organic compounds are simultaneously utilized to degrade the hydrocarbon contaminants. During active remediation, the TOC and hydrocarbon contaminant concentrations would be monitored to evaluate the rate of bioremediation progress.

4.4 Soil Gas Survey

The results of the soil gas survey for the seven monitoring points that were installed in the tankfield area are summarized in Table 4. At these locations, the soil gas concentrations of oxygen, carbon dioxide and methane were determined. Only one location, VP-6 indicated a depletion of oxygen levels relative to ambient levels (approximately 20% O₂). VP-6 also had the highest percent CO₂ and percent methane levels relative to the other monitoring points. Interpretation of these data suggests that at the depths and locations that vapor points VP-1, VP-2, VP-3, VP-4, VP-5, and VP-7 were not ideal. These monitoring points were not effectively isolated from influence from the surface, thereby allowing diffusion of oxygen. VP-1, VP-2, VP-4 and VP-6 were installed in known areas of hydrocarbon contamination based on data available from previous investigations. However, the site soils, as well as the



distribution of the contaminant are reported to be very heterogeneous, making it possible that the soil gas points were not installed at the optimum depths or locations to monitor oxygen uptake. Only the results obtained from VP-6 were indicative of on-going biological activity (depletion of O₂ and production of CO₂ and methane).

4.5 Bioventing Evaluation

Bioventing is the term used to describe the merger of soil vapor extraction technologies with bioremediation. It is an *in situ* process where aerobic biodegradation of the contaminant(s) is promoted by the movement of air through the soils to increase soil oxygen levels. The addition of oxygen to the soil promotes degradation of the contaminant(s) by the indigenous microbial population.

Whether or not a site is a good candidate for bioventing is based on the results of a field test referred to as an *in situ* respiration test. In this test, fresh air is introduced into the subsurface in a contaminated area via vapor extraction techniques, bringing the levels of oxygen to approximately 21%. The vapor extraction system is then shut off and the rate at which the oxygen is utilized by the indigenous microorganisms is monitored over a 40- to 80- hour monitoring period. Soil gas monitoring points in areas amenable to bioventing will show a significant decline in oxygen over the monitoring period.

The soil gases in all seven monitoring points were monitored to evaluate the oxygen utilization rates at each location. However, as was discussed previously in the soil gas monitoring section, only monitoring point VP-6 had data which is indicative of a successful bioventing application. The results for all monitoring points for the *in situ* respiration test are presented in Table 5. Graphical presentation of the results for vapor point VP-6 are illustrated in Figure 6. Linear regression analysis was used to determine k, the estimated rate of oxygen utilization for VP-6. It was determined to be 0.28% /hr, which is



in the range of rates reported by other *in situ* respiration studies (Hinchee, 1993).

5.0 CONCLUSION / RECOMMENDATIONS

The data obtained from this initial bioremediation evaluation at the Quebecor site suggest that site conditions are conducive for the implementation of bioremediation techniques. The microbial enumerations indicated the presence of an adequate indigenous microbial population; the pH was in an acceptable range for microbial activity and inorganic nutrient levels were at acceptable levels.

~~X~~ The soil gas survey and bioventing evaluation suggest that bioventing may be a viable *in situ* remediation technique for the site. However, the results also suggest that there is a potential for 'short-circuiting'. In order to effectively implement a full-scale remediation system, an additional soil gas survey and *in situ* remediation study may be warranted to insure proper and effective placement of the treatment system components. Performance of this additional study would entail the use of multiple soil gas sampling probes at different depths. This information would allow more effective characterization of the site in regards to the heterogeneities present.

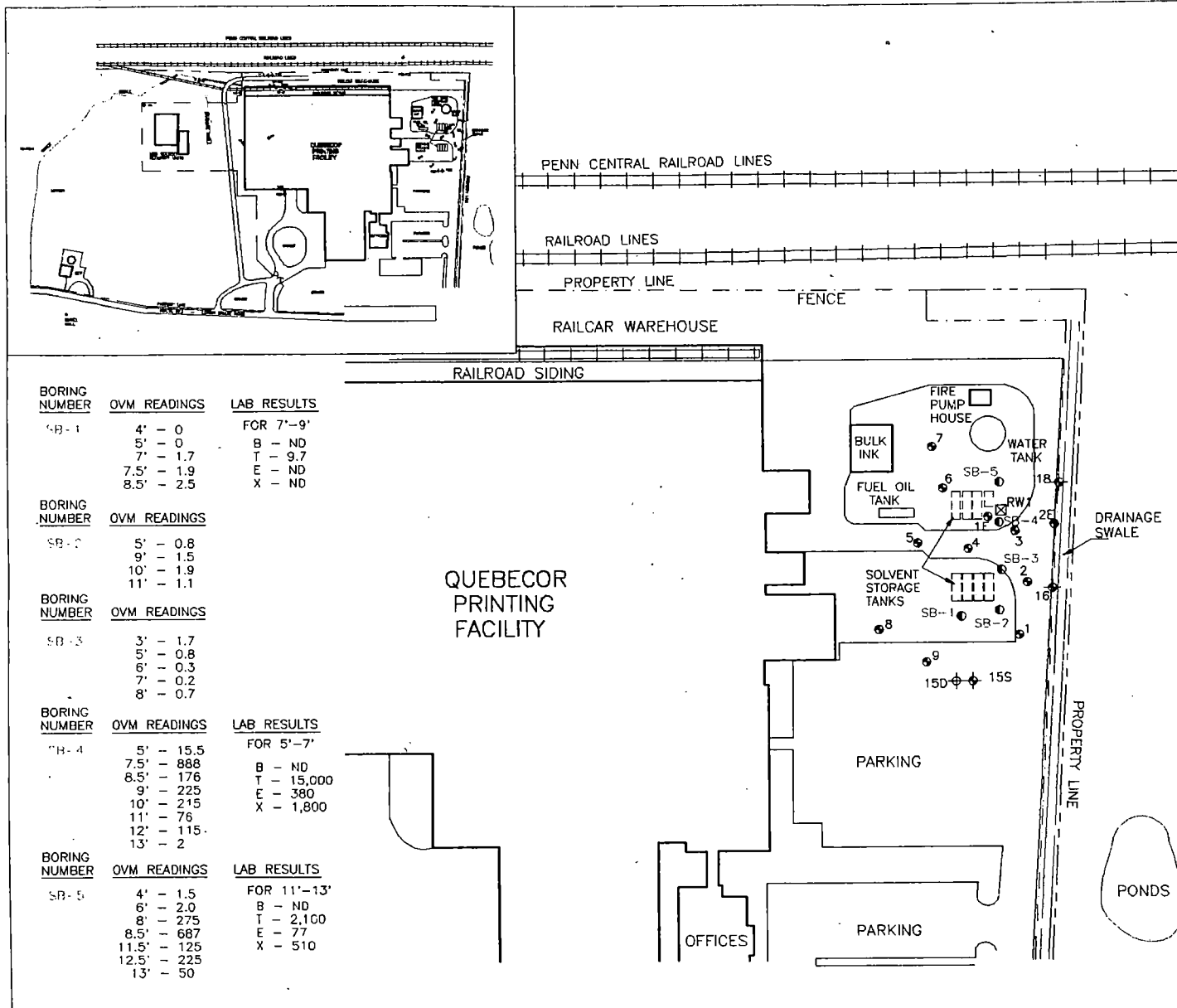
6.0. REFERENCES

Hinchee, R.E., 1993. Bioventing of Petroleum Hydrocarbons. In In-Situ Bioremediation of Ground Water and Geological Materials: A Review of Technologies. Robert S. Kerr Environmental Research Laboratory. Office of Research and Development. U.S. Environmental Protection Agency. Ada, Oklahoma. 74820. EPA/600/R-93/124.

LEGEND

- MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ DEEP MONITORING WELL
- SOIL BORING LOCATION
- B BENZENE
- T TOLUENE
- E ETHYLBENZENE
- X XYLENE
- ND NOT DETECTED

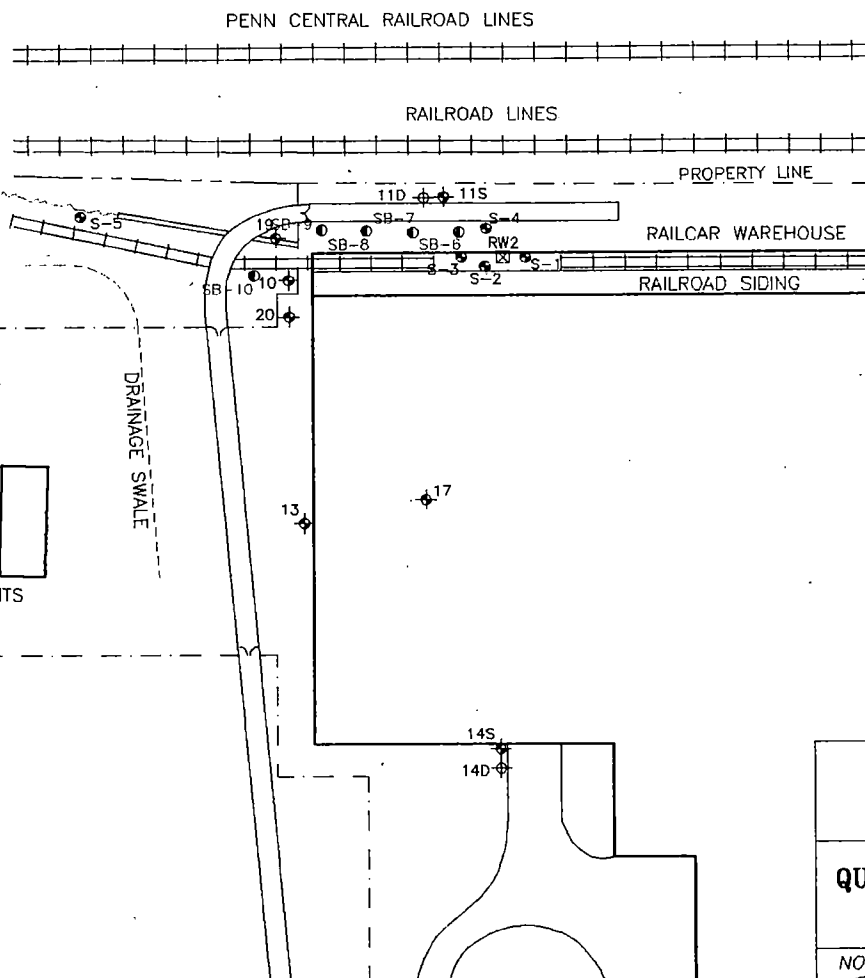
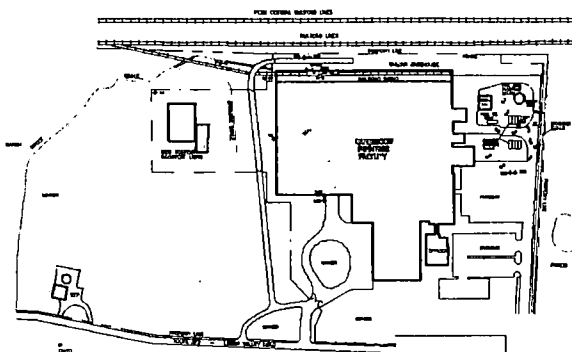
NOTES: - ALL LAB RESULTS IN MICROGRAMS
PER KILOGRAM (ug/kg)
- NO SAMPLES WERE ANALYZED
FROM SB-2 AND SB-3
- OVM READINGS ARE UNITLESS



LEGEND

- MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊕ DEEP MONITORING WELL
- SOIL BORING LOCATION
- B BENZENE
- T TOLUENE
- E ETHYLBENZENE
- X XYLENE
- ND NOT DETECTED

NOTES: - ALL LAB RESULTS IN MICROGRAMS
PER KILOGRAM (ug/kg)
- NO SAMPLES WERE ANALYZED
FROM SB-8 AND AB-10
- OVM READINGS ARE UNITLESS



BORING NUMBER	OVM READINGS	LAB RESULTS
SB-6	5' - 15.5	FOR 9'-11'
	6.5' - 73	B - ND
	8' - 135	T - 28,000
	10' - 177	E - 1,800
	12' - 2.5	X - 10,000
	13' - 2.5	

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-7	8.5' - 13.5	FOR 8'-10'
	9.5' - 12.2	B - ND
	11' - 8.5	T - 11
	11.5' - 6	E - ND
	12.5' - 0.2	X - ND
	13' - 0	
	14' - 0	

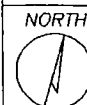
BORING NUMBER	OVM READINGS
SB-8	5' - 0
	7' - 0
	9.5' - 0
	10' - 0
	10.5' - 0

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-9	5' - 0	FOR 5'-7'
	6' - 0	B - ND
	7' - 0	T - 6
	8' - 0	E - ND
	9' - 0	X - ND
	10' - 0	
	11' - 0	

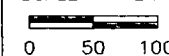
BORING NUMBER	OVM READINGS
SB-10	7.5' - 78
	9' - 63.5
	10' - 59
	11.5' - 10.9
	12.5' - 2.1

**SOIL BORING LOCATIONS SHOWING
OVM READINGS AND LABORATORY
ANALYTICAL RESULTS
13 MAY 1994**

**QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA**



SCALE IN FEET

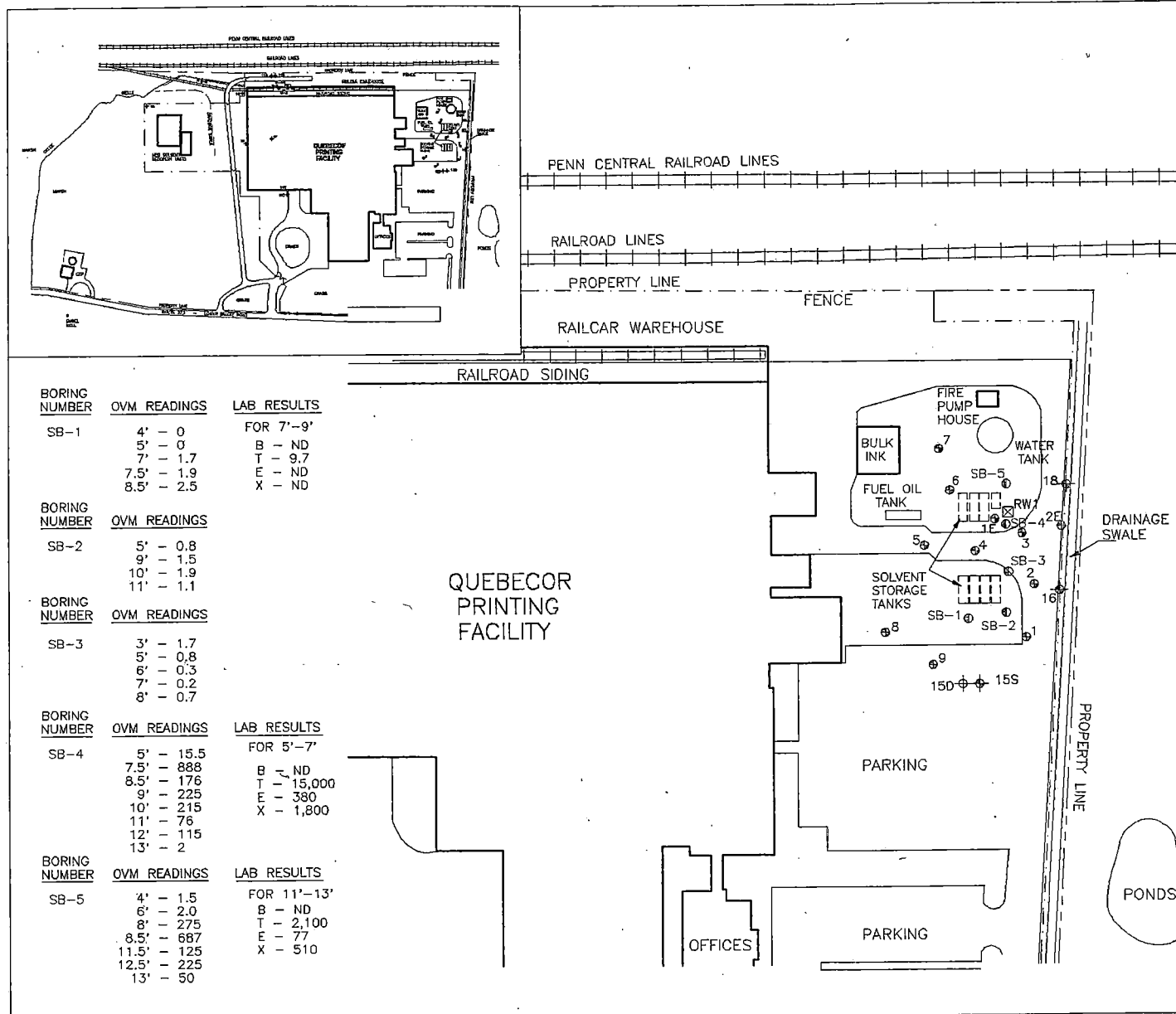


DATE	SOURCE
9-24-93	B
DWG #	FIGURE
PS0046C	2 APP C

LEGEND

- ⊙ MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊖ DEEP MONITORING WELL
- ⊙ SOIL BORING LOCATION
- B BENZENE
- T TOLUENE
- E ETHYLBENZENE
- X XYLENE
- ND NOT DETECTED

NOTES: - ALL LAB RESULTS IN PARTS
PER MILLION (ppm)
- NO SAMPLES WERE ANALYZED
FROM SB-2 AND SB-3
- OVM READINGS ARE UNITLESS



BORING NUMBER	OVM READINGS	LAB RESULTS
SB-1	4' - 0	FOR 7'-9'
	5' - 0	B - ND
	7' - 1.7	T - 9.7
	7.5' - 1.9	E - ND
	8.5' - 2.5	X - ND

BORING NUMBER	OVM READINGS
SB-2	5' - 0.8
	9' - 1.5
	10' - 1.9
	11' - 1.1

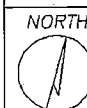
BORING NUMBER	OVM READINGS
SB-3	3' - 1.7
	5' - 0.8
	6' - 0.3
	7' - 0.2
	8' - 0.7

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-4	5' - 15.5	FOR 5'-7'
	7.5' - 888	B - ND
	8.5' - 176	T - 15,000
	9' - 225	E - 380
	10' - 215	X - 1,800
	11' - 76	
	12' - 115	
	13' - 2	

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-5	4' - 1.5	FOR 11'-13'
	6' - 2.0	B - ND
	8' - 275	T - 2,100
	8.5' - 687	E - 77
	11.5' - 125	X - 510
	12.5' - 225	
	13' - 50	

SOIL BORING LOCATIONS SHOWING
OVM READINGS AND LABORATORY
ANALYTICAL RESULTS
13 MAY 1993

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA



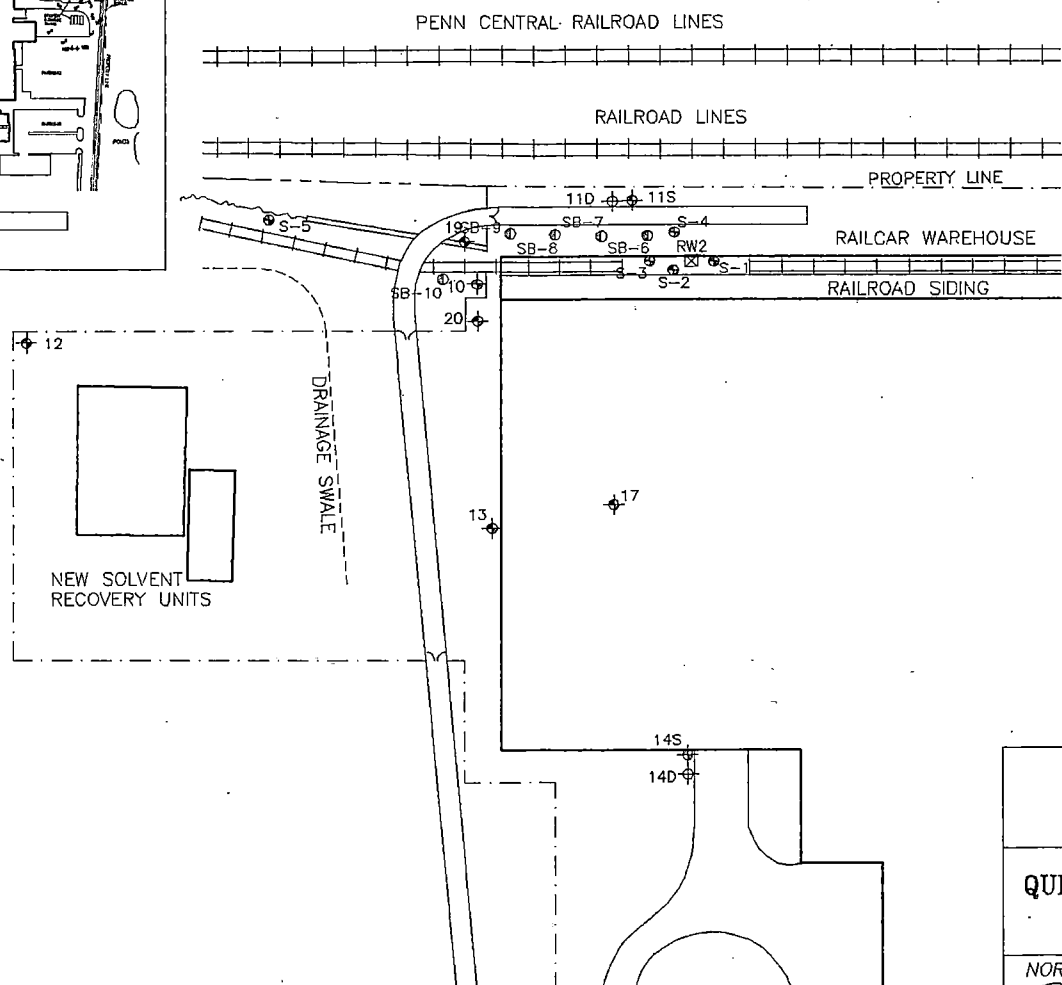
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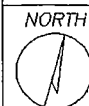
SOURCE
B
FIGURE
1
APP C

- NOTES: - ALL LAB RESULTS IN PARTS
PER MILLION (ppm)
- NO SAMPLES WERE ANALYZED
FROM SB-8 AND AB-10
- OVM READINGS ARE UNITLESS


<u>BORING NUMBER</u>	<u>OVM READINGS</u>
SB-10	7.5' - 78
	9' - 63.5
	10' - 59
	11.5' - 10.9
	12.5' - 2.1



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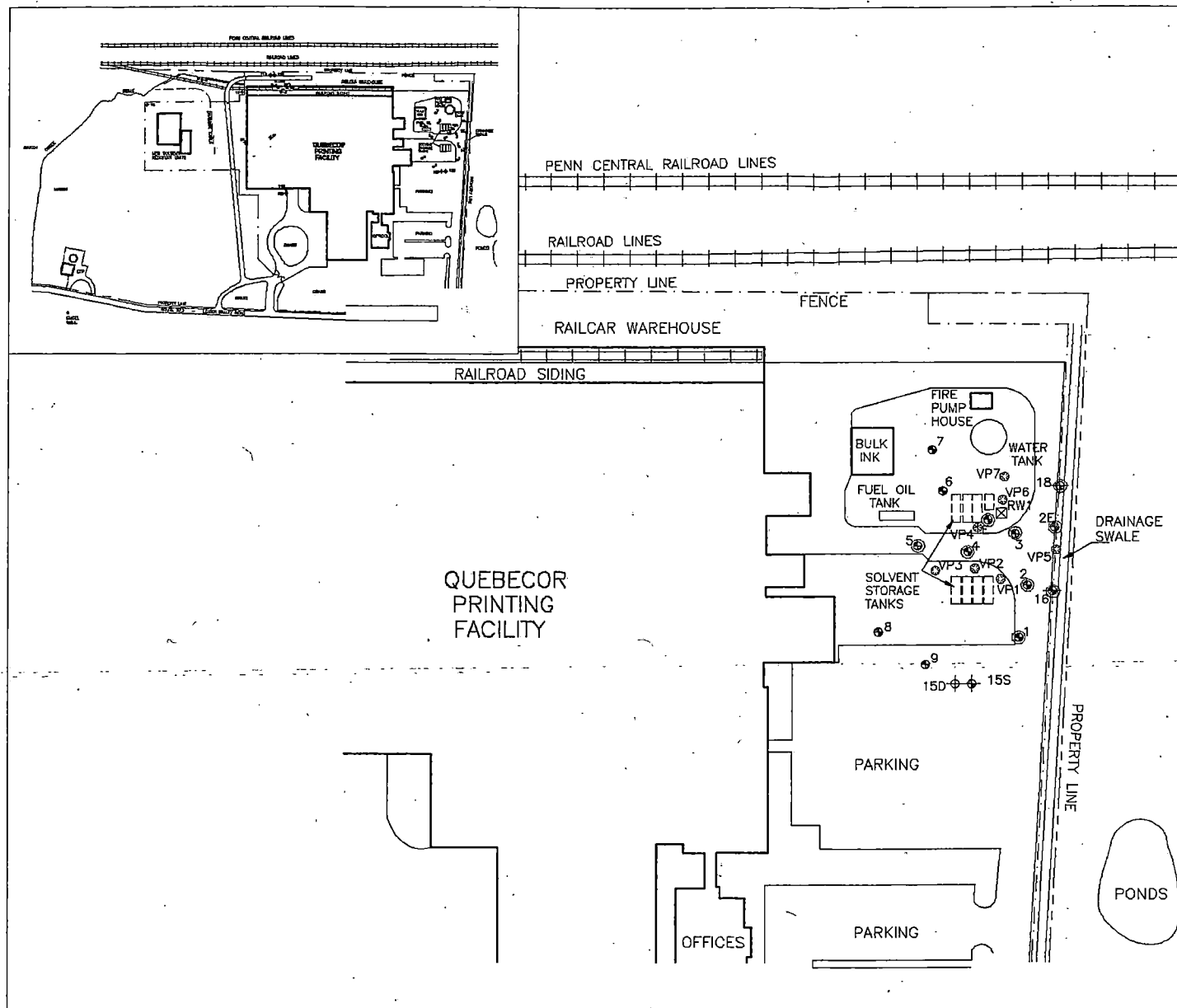
0 50 100

DATE	9-24-93
DWG #	PS0046C

SOURCE B
FIGURE 2 APP. C

LEGEND

- ⊙ MONITORING WELL
- ⊠ RECOVERY WELL
- ⊕ SHALLOW MONITORING WELL
- ⊖ DEEP MONITORING WELL
- ⊙ WELL MONITORING POINT
- ⊙ VAPOR EXTRACTION WELL
- ⊙ VAPOR MONITORING POINT/
SOIL GAS SAMPLING LOCATION



EXTRACTION AND MONITORING POINTS

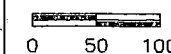
VAPOR EXTRACTION TEST
25 & 27 MAY 1994

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA

NORTH



SCALE IN FEET



DATE
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PS0046B

SOURCE
B

FIGURE
3
APP C

10/12/93

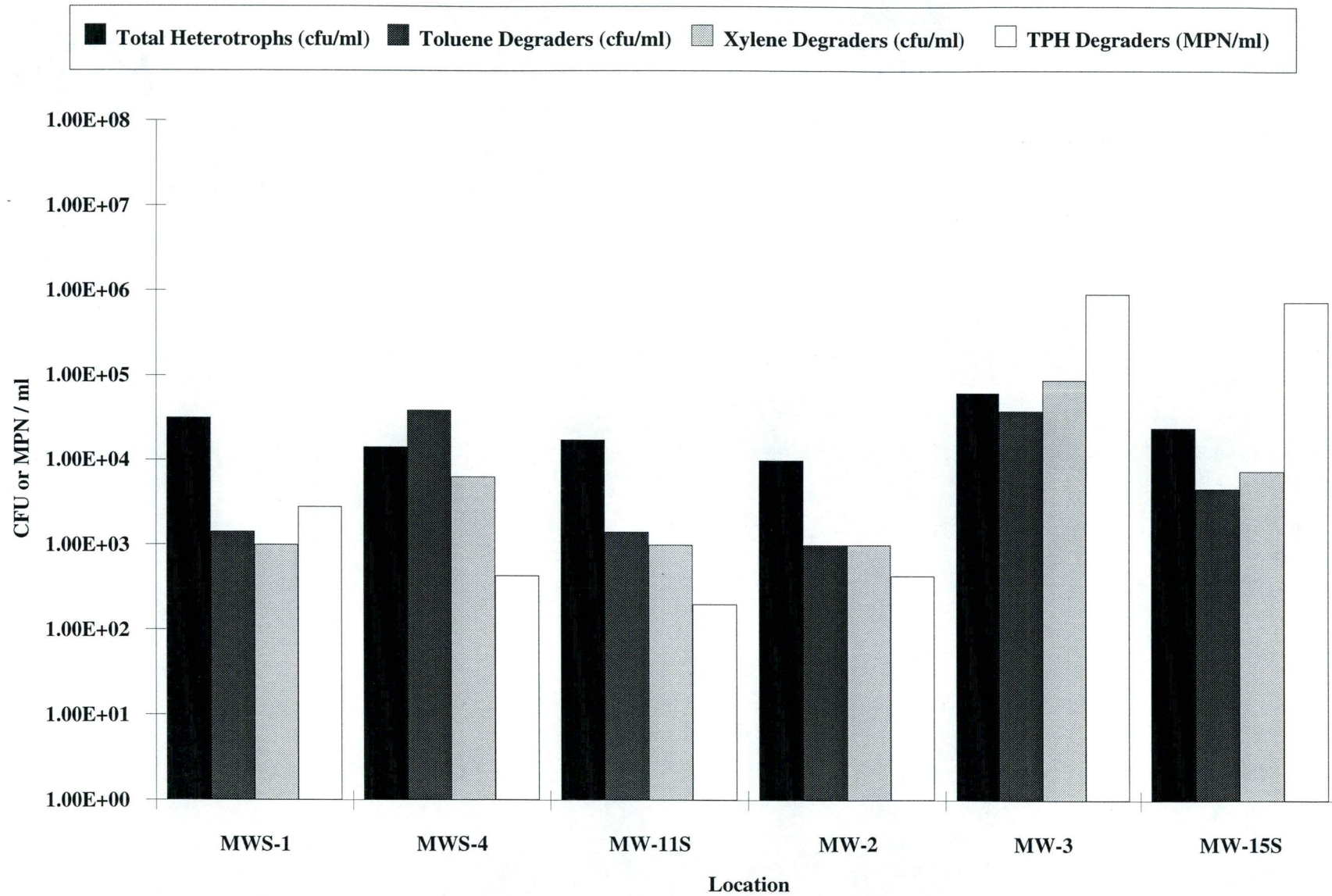


Figure 4. Results of the Microbial Enumerations Performed on the Groundwater Samples

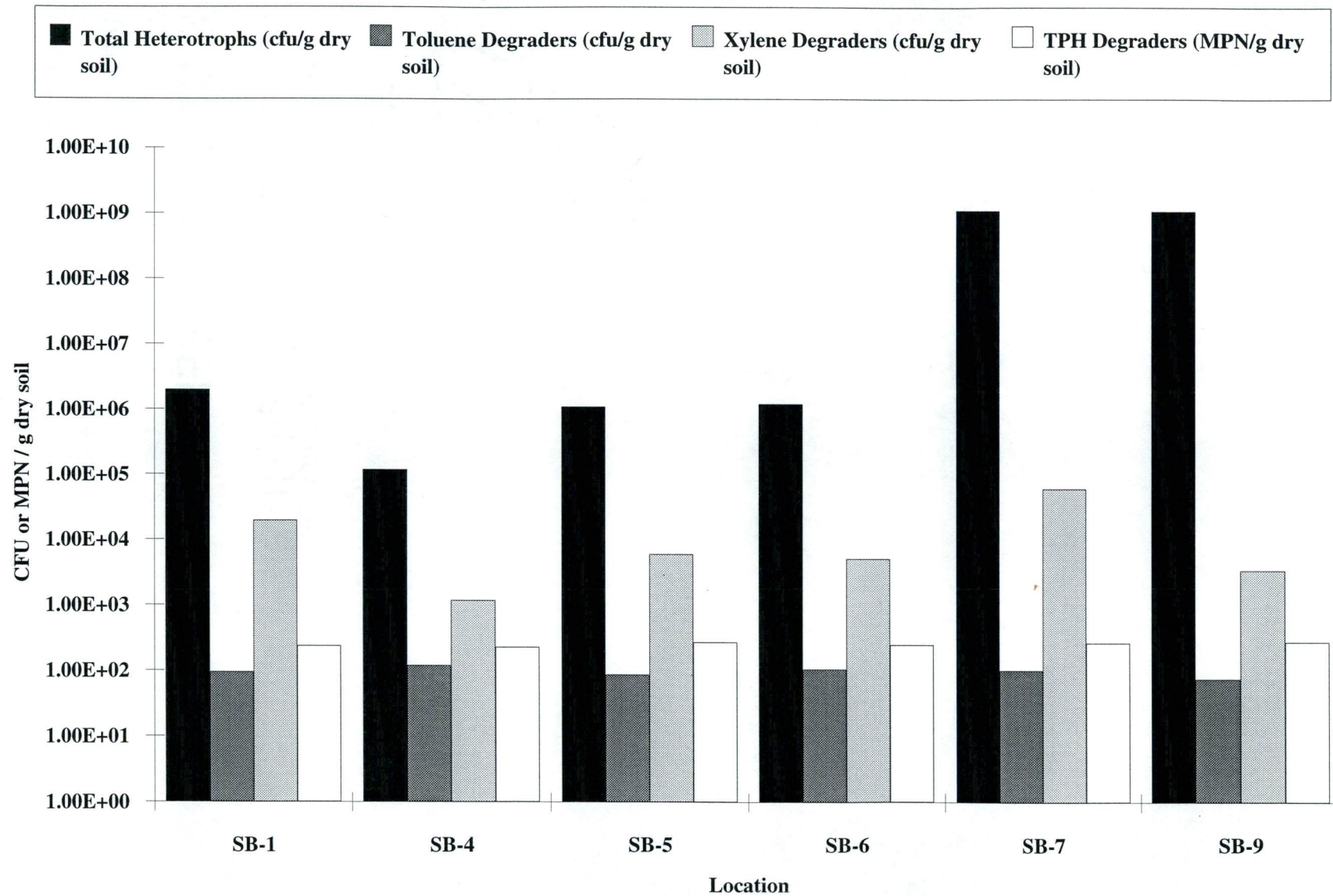


Figure 5. Results of the Microbial Enumerations Performed on the Soil Samples

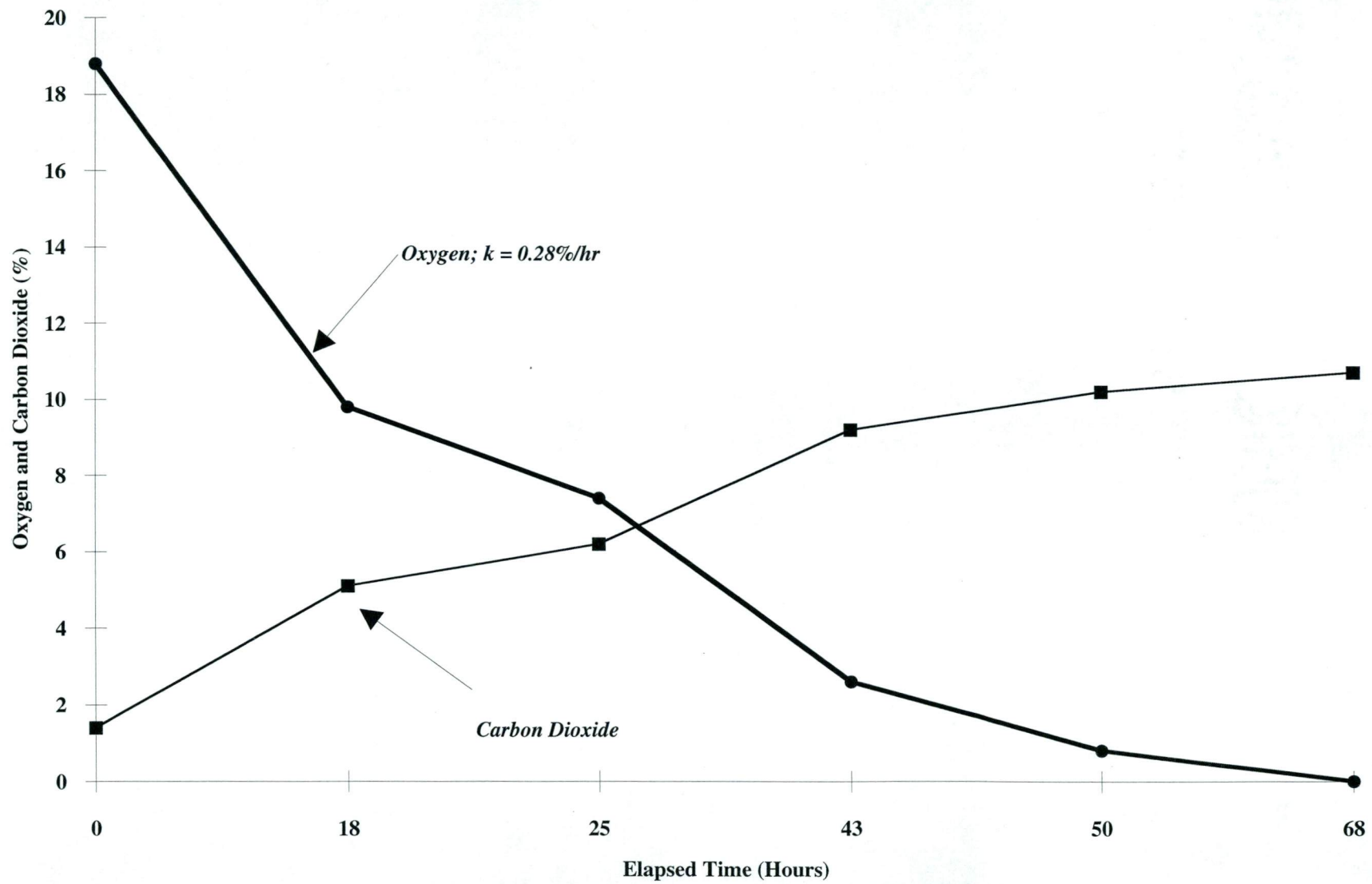


Figure 6. In Situ Respiration Test Results for Monitoring Point VP-6

Table 1. Bioremediation Groundwater and Soil Sampling Parameters

Groundwater

	Parameter	Comment
Microbial Enumerations	Total Heterotrophs	Spread Plate on Trypticase Soy Agar; 14 day incubation at room temperature
	Toluene Degradars	Spread Plate on Bushnell-Haas Agar in an atmosphere. of tol. vapors; 14 days incub. at room temp.
	Xylene Degradars	Spread Plate on Bushnell-Haas Agar in an atmosphere of xyl. vapors; 14 days incub. at room temp.
	TPH Degradars	Sheen Screen Most Probable Number with #2 Fuel Oil as Carbon and Energy Source
Organic Analyses	Total Organic Carbon	Determined by U.S. EPA method 415.1
	Benzene	Determined by U.S. EPA method 5030A/8021 (GC)
	Toluene	Determined by U.S. EPA method 5030A/8021 (GC)
	Ethylbenzene	Determined by U.S. EPA method 5030A/8021 (GC)
	m/p Xylene	Determined by U.S. EPA method 5030A/8021 (GC)
	o - Xylene	Determined by U.S. EPA method 5030A/8021 (GC)
Inorganic Analyses	Nitrate	Determined using a Corning pH/ISE meter and Orion Nitrate Electrode
	Ammonia	Determined by U.S. EPA method 350.2
	Phosphate	Determined by U.S. EPA method 365.2
	Iron	Determined using TPTZ reagent
	Sulfate	Determined by U.S. EPA method 415.1
Other	pH	Determined using a Corning pH/ISE meter and combination electrode

Soil

	Parameter	Comment
Microbial Enumerations	Total Heterotrophs	Spread Plate on Trypticase Soy Agar; 14 day incubation at room temperature
	Toluene Degradars	Spread Plate on Bushnell-Haas Agar in an atmosphere. of tol. vapors; 14 days incub. at room temp.
	Xylene Degradars	Spread Plate on Bushnell-Haas Agar in an atmosphere of xyl. vapors; 14 days incub. at room temp.
	TPH Degradars	Sheen Screen Most Probable Number with #2 Fuel Oil as Carbon and Energy Source
Organic Analyses	Benzene	Determined by U.S. EPA method 5030A/8021 (GC)
	Toluene	Determined by U.S. EPA method 5030A/8021 (GC)
	Ethylbenzene	Determined by U.S. EPA method 5030A/8021 (GC)
	m/p Xylene	Determined by U.S. EPA method 5030A/8021 (GC)
	o - Xylene	Determined by U.S. EPA method 5030A/8021 (GC)
Inorganic Analyses	Nitrate	Determined on aqueous soil extracts using Cadmium Reduction
	Ammonia	Determined on aqueous soil extracts using direct Nesslerization
	Phosphate	Determined on Bray's extracted soils using the molybdate technique
Other	pH	Determined using a Corning pH/ISE meter and combination electrode on soil slurries
	Soil Moisture	Determined by the difference between wet and air dry weights

Table 2. Summary of the Groundwater Sampling Results for the Railroad and Tank Field Areas

		Total Heterotrophs (cfu/ml)	Toluene Degraders (cfu/ml)	Xylene Degraders (cfu/ml)	TPH Degraders (MPN/ml)	TOC (ppm)	Benzene (µg/l)	Toluene (µg/l)	Ethylbenzene (µg/l)	m/p Xylene (µg/l)	o - Xylene (µg/l)	Total Xylenes (µg/l)
Railroad Area	MWS-1	3.16E+04	1.41E+03	1.00E+03	2.80E+03	143.40	22	14,000	190	980	260	1,200
	MWS-4	1.41E+04	3.87E+04	6.33E+03	4.30E+02	77.85	9.7	83,000	480	2,200	660	2,900
	MW-11S	1.73E+04	1.41E+03	1.00E+03	2.00E+02	13.65	ND	ND	ND	ND	ND	ND
Tank Field Area	MW-2	1.00E+04	1.00E+03	1.00E+03	4.30E+02	27.40	ND	1.3	ND	1.7	ND	1.7
	MW-3	6.32E+04	3.87E+04	8.94E+04	9.30E+05	43.93	3.4	1,900	66	500	130	630
	MW-15S	2.45E+04	4.69E+03	7.55E+03	7.50E+05	39.28	ND	ND	ND	ND	ND	ND

		pH	Nitrate (ppm)	Ammonia (ppm)	Phosphate (ppm)	Iron (ppm)	Sulfate (ppm)
Railroad Area	MWS-1	6.78	1.82	0.22	0.20	1.10	ND
	MWS-4	6.19	1.33	1.02	0.47	>1.98	24.5
	MW-11S	6.02	1.48	1.31	0.41	>1.98	56.0
Tank Field Area	MW-2	6.21	0.70	0.06	0.16	>1.98	48.0
	MW-3	6.83	1.20	0.23	0.25	>1.98	28.5
	MW-15S	7.36	1.05	0.07	0.21	>1.98	25.0

Notes:

cfu - colony-forming-unit

ml - milliliter

MPN -most probable number

ppm - parts per million

µg - microgram

l - liter

ND - less than the minimum detection limit

Table 3. Summary of the Soil Sampling Results for the Railroad and Tank Field Areas

		Total Heterotrophs (cfu/g dry soil)	Toluene Degraders (cfu/g dry soil)	Xylene Degraders (cfu/g dry soil)	TPH Degraders (MPN/g dry soil)	Benzene (µg/Kg)	Toluene (µg/Kg)	Ethylbenzene (µg/Kg)	m/p Xylene (µg/Kg)	o - Xylene (µg/Kg)	Total Xylenes (µg/Kg)
Tank Field Area	SB-1 7' - 9'	1.99E+06	9.50E+01	1.96E+04	2.37E+02	ND	9.7	ND	ND	ND	ND
	SB-4 5' - 7'	1.17E+05	1.19E+02	1.17E+03	2.30E+02	ND	15,000	380	1,400	390	1,800
	SB-5 11' - 13'	1.10E+06	8.70E+01	6.02E+03	2.73E+02	ND	2,100	77	390	130	510
Railroad Area	SB-6 9' - 11'	1.20E+06	1.05E+02	5.11E+03	2.49E+02	ND	28,000	1,800	8,100	2,100	10,000
	SB-7 8' - 10'	1.12E+09	1.02E+02	6.11E+04	2.69E+02	ND	11	ND	ND	ND	ND
	SB-9 9' - 11'	1.09E+09	7.60E+01	3.45E+03	2.75E+02	ND	6.0	ND	ND	ND	ND

		pH	Nitrate (mg/Kg)	Ammonia (mg/Kg)	Phosphate (mg/Kg)	Moisture (%)
Tank Field Area	SB-1 7' - 9'	6.0 - 7.0	2	114	68	21.0
	SB-4 5' - 7'	6.0 - 7.0	6	56	52	23.4
	SB-5 11' - 13'	6.0 - 7.0	37	51	90	17.4
Railroad Area	SB-6 9' - 11'	6.0 - 7.0	8	77	37	16.9
	SB-7 8' - 10'	6.0 - 7.0	3	76	104	10.3
	SB-9 9' - 11'	6.0 - 7.0	26	83	34	16.6

Notes:

cfu - colony-forming-unit

g - gram

MPN -most probable number

ppm - parts per million

µg - microgram

Kg - kilogram

ND - less than the minimum detection limit

Table 4. Summary of Soil Gas Sampling Results

Date	Time		VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
5/23/94	8:20 AM	% Oxygen	16.8	20.6	20.6	20.1	20.4	1.2	20.8
		% Carbon Dioxide	2.6	0.1	0.1	0.9	0.8	8.1	0.2
		% Methane	6.9	0.3	0.1	0.1	0.3	54.5	0.7

Table 5. In Situ Respiration Test Monitoring Results

Date	Time								
5/25/94	1:30 PM	Began VR Test on Wells 1E and 3 (Ran 8 Hours)							
5/25/94	2:30 PM		VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
		% Oxygen	19.9	19.9	20.8	19.5	20.0	20.7	20.5
		% Carbon Dioxide	0.6	0.4	0.0	0.6	0.4	0.0	0.3
		% Methane	0.4	0.2	0.1	0.4	0.1	0.1	0.1
5/25/94	5:30 PM		VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
		% Oxygen	19.4	19.5	19.9	19.9	20.2	20.4	19.8
		% Carbon Dioxide	0.3	0.3	0.2	0.6	0.1	0.0	0.6
		% Methane	0.1	0.0	0.0	0.0	0.0	0.0	0.0
5/25/94	9:30 PM	VR Test Ends							
5/25/94	10:00 PM		VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
		% Oxygen	19.7	19.0	19.5	19.6	19.5	19.2	19.4
		% Carbon Dioxide	0.2	0.4	0.3	0.8	0.4	0.4	0.3
		% Methane	0.3	0.0	0.0	0.0	0.0	0.0	0.0
5/26/94	10:30 AM		VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
		% Oxygen	19.1	19.3	19.3	19.3	19.5	14.4	19.6
		% Carbon Dioxide	0.6	0.2	0.2	0.1	0.1	2.7	0.3
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/26/94	12:30 PM		VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
		% Oxygen	18.9	19.4	19.3	19.3	19.0	10.9	19.2
		% Carbon Dioxide	0.4	0.2	0.2	0.1	0.3	3.9	0.6
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5. continued

			VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
5/27/94	10:00 AM	% Oxygen	18.8	19.3	19.5	19.4	19.9	12.4	19.6
		% Carbon Dioxide	0.4	0.2	0.2	0.9	0.0	3.7	0.4
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

5/27/94 10:47 AM Began VR Test on MW-1E, Ran for 1 hr 45 min.

5/27/94 1:18 PM Began VR Test on MW-3, Ran for 2 hrs 4 min.

			VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
5/27/94	4:00 PM	% Oxygen	19.5	19.9	20.1	20.2	20.1	18.8	20.1
		% Carbon Dioxide	0.3	0.2	0.1	0.1	0.1	1.4	0.6
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

			VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
5/28/94	10:00 AM	% Oxygen	19.2	19.2	19.3	19.6	19.5	9.8	19.6
		% Carbon Dioxide	0.3	0.2	0.2	0.1	0.1	5.1	0.6
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

			VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
5/28/94	5:00 PM	% Oxygen	19.4	9.5	19.7	19.6	19.7	7.4	19.6
		% Carbon Dioxide	0.2	0.1	0	0.1	0.1	6.2	0.6
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

			VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
5/29/94	11:00 AM	% Oxygen	18.2	18.6	18.7	18.7	18.8	2.6	19.5
		% Carbon Dioxide	0.9	0.2	0.2	0.2	0.2	9.2	0.4
		% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
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5/29/94 6:00 PM

% Oxygen	19.3	19.3	19.3	19.3	19.1	0.8	19.0
% Carbon Dioxide	0.1	0.1	0.1	0.1	0.4	10.2	0.6
% Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5. continued

5/30/94 12:00 PM

	VP-1	VP-2	VP-3	VP-4	VP-5	VP-6	VP-7
% Oxygen	19.3	19.3	19.4	19.3	18.9	0.0	19.8
% Carbon Dioxide	0.0	0.0	0.0	0.2	0.6	10.7	0.4
% Methane	0.0	0.0	0.0	0.0	0.0	3.2	0.0



BIOVENTING FEASIBILITY STUDY
FOR THE QUEBECOR, INC. SITE
ATGLEN, PENNSYLVANIA

PREPARED FOR:

GROUNDWATER & ENVIRONMENTAL SERVICES, INC.
410 EAGLEVIEW BLVD., SUITE 110
EXTON, PENNSYLVANIA 19341

PREPARED BY:

TERRA SYSTEMS, INC.
1035 PHILADELPHIA PIKE, SUITE E
WILMINGTON, DELAWARE 19809

JULY 27, 1994

EXECUTIVE SUMMARY

A bioremediation treatability assessment study was conducted for the hydrocarbon contaminated soil at the Quebecor, Inc. site in Atglen, Pennsylvania at the request of Groundwater & Environmental Services, Inc. (GES). A soil and groundwater sample from the site were subjected to feasibility studies by Terra Systems, Inc. (TSI) on behalf of GES to evaluate bioventing. Terra Systems concludes the following:

1. There were high counts of both heterotrophic (1.8×10^6 colony-forming-units/gram <cfu/g>) and hydrocarbon-utilizing (2.8×10^6 cfu/g) microbes in the initial soil samples indicating that conditions were favorable for microbial growth. These high counts are also an indication that the microbial population was acclimated to biodegrading the organic contaminants.
2. Soil samples contained low concentrations of toluene and ethylbenzene.
3. Soil venting alone appeared to be a viable remedial alternative for the unsaturated soils contaminated with petroleum hydrocarbon at the Quebecor site based upon the in situ bioventing treatability study. Soils from the area studied showed a 96 percent reduction in toluene over the six week study.
4. It does not appear that traditional in situ bioremediation will be appropriate at this site because of the potential soil plugging that will occur if nutrient enriched groundwater is injected into the formation.

1.0 INTRODUCTION

Groundwater & Environmental Services, Inc. (GES) engaged Terra Systems, Inc. (TSI) to investigate the feasibility of using bioventing to remediate organic contaminated soils at the Quebecor, Inc. site in Atglen, Pennsylvania. The organic contaminant of concern is reported to be toluene.

Bioventing is a process that promotes the activity of the native soil microbes to biodegrade the organic contaminants to carbon dioxide, cell mass, water, and salts by overcoming limitations on their growth. Bioventing supplies oxygen to the contaminated soil in the vadose zone by injecting air or by pulling air into the contaminated soil with vacuum extraction. For the option with vacuum extraction, the volatiles can be collected and captured on activated carbon or destroyed with a thermal treatment unit. At slow air injection rates, biodegradation of the contaminants can occur in the vadose zone before a receptor will be impacted. Both bioventing and vacuum extraction use similar equipment, but the major difference between the two is that the air flow rate in bioventing is limited to optimize biodegradation of the contaminants rather than volatilization. Bioventing can also treat compounds with a lower vapor pressure than can vacuum extraction because the microbes can attack these compounds and they will not partition into the vapor phase. For bioventing to be feasible, the organic contaminants must be biodegradable, and the soil microbial population must have developed the enzyme systems which will allow them to biodegrade the organic contaminants. To facilitate the process, the required inorganic nutrient (chiefly nitrogen and phosphate) are added to the soil, and the soil is aerated by venting. Moist soil conditions should be maintained to promote microbial growth.

A Shelby tube of soil was collected from the Atglen site at a depth of 7 to 9 feet below grade by G.E.S., Inc. The samples were shipped to the TSI Laboratory under chain-of-custody procedures. A copy of the completed chain-of-custody form is found in Appendix A. The soil sample was used to:

- * Characterize the contaminants
- * Determine if an active microbial population is present.
- * Determine whether the microbes could biodegrade the contaminants.
- * Determine if bioventing or vacuum extraction could remove the contaminants.
- * Determine if a nutrient enriched groundwater solution would cause precipitation.

This report summarizes the results of this investigation and provides an evaluation of the potential effectiveness of bioventing or vacuum extraction to remediate the contaminated soil.

2.0 CONTAMINANT CHARACTERIZATION

2.1 METHODS

In preparing the column for the bioventing study, the top one inch of the soil within the Shelby tube was removed and discarded. A soil sample (approximately 300 grams) was then collected from the top of the column and analyzed for benzene, toluene, ethylbenzene, and xylenes according to the protocols for SWA 846 EPA Method 8020. This procedure uses a purge and trap unit to desorb the organics from the soil, collect them on a trap, and then expose them to a photoionization detector.

2.2 ORGANIC CONTAMINANT RESULTS

The initial soil sample contained ^{22.0}<0.6 mg/kg benzene, ^{16000,000}38 ug/kg toluene, 18 ug/kg ethylbenzene, ^{1800,000}39 ug/kg m,p-xylene, and ^{160000,000}7.5 ug/kg o-xylenes. } clear

The concentrations of BTEX for the initial soil sample is summarized in Table 4 and the analytical reports are presented in Appendix A.

3.0 INORGANIC NUTRIENTS

3.1 INORGANIC NUTRIENT ANALYSES

A soil sample collected from the Atglen site at a depth of 7 to 9 feet below grade was analyzed for nitrate-nitrogen, total Kjeldahl nitrogen, phosphorus, zinc, sulfur, potassium, calcium, magnesium, pH, cation exchange capacity, organic matter, boron, iron, manganese, copper, sodium, salts, texture, and grain size distribution. MVTL Laboratories, Inc. of New Ulm, MN conducted these analyses.

Nitrogen, phosphorus, and oxygen are the primary nutrients required for biodegradation of hydrocarbons. Nitrate-nitrogen is an inorganic form of nitrogen readily available to most microbes. Nitrite-nitrogen is a reduced form of nitrate. High levels of nitrite would indicate that nitrate reduction was occurring in the soil. Total Kjeldahl nitrogen (TKN) is a measure of the organic nitrogen and ammonia in the soil. Zinc, sulfur, potassium, calcium, and magnesium are needed as minor nutrients. Boron, iron, manganese, copper and sodium are needed as trace minerals. The optimal pH for microbial growth is between 6 and 8. The cation exchange capacity is a measure of the ability of a soil to retain cations such as NH_4^+ , K^+ , Ca^{++} , and Mg^{++} from solution; soils with high clay or organic matter contents generally have higher cation exchange capacities. The organic matter in the soil is important in determining the nutrient requirements of a soil.

3.2 INORGANIC NUTRIENT RESULTS

The results of the inorganic analyses for the soil sample are presented in Table 1. The nitrate-nitrogen levels was 2.6 ppm. There was a relatively high TKN at 220 ppm. The phosphate level was 5 ppm. The potassium, zinc, sulfur, calcium, and magnesium levels were 10, 0.5, 26, 800, and 150 ppm respectively. The soil pH was 6.6. The trace minerals were boron at 0.2 ppm, iron 67.2 ppm, manganese 4.9 ppm, copper 0.7 ppm and sodium 13 ppm. The cation exchange capacity of the soil was 5.3 millequivalents per 100 grams. The organic matter was 2.3% which is considered to be low.

The particle size of the soil determined from the sieve analyses is reported in Table 2. The soil appeared to be predominantly a fine sand (54%) with some medium sand (19.2%), gravel (9.4%), coarse sand (4.2%), and moderately high clay and silt content (13.4%). (Please refer to Appendix A.)

3.3 INORGANIC NUTRIENT ANALYSES DISCUSSION

There appeared to be adequate levels of nitrogen and phosphorus in this soil to support the biodegradation of the relatively low levels of hydrocarbon contaminants detected in the soil. There appeared to be adequate levels of the minor and trace nutrients. The soil pH was 6.6

and should be within the optimal range for microbial growth.

3.4 SOIL CHARACTERIZATION

The particle size distribution of the soil suggests that bioventing or vapor extraction should be successful in this fine sand. Considering the clay content in the soil, the determination of the ability to move oxygen through the formation would need to be confirmed via a high vapor extraction test.

4.0 MICROBIAL ENUMERATIONS

4.1 METHODS

The soil sample was analyzed to enumerate heterotrophic bacteria and hydrocarbon-utilizing bacteria using standard microbiological plating techniques. The heterotrophic counts provided a measure of the total numbers of organisms in the soil capable of utilizing the organic compounds in nutrient agar as their substrate. Nutrient agar was prepared from beef extract and peptone and contains sugars, inorganic nutrients, vitamins, and their other components necessary for microbial growth. The heterotrophic counts were made using the pour-plate technique in which molten agar at approximately 45 ° C was poured over the dilutions of the sample and the agar allowed to solidify. The heterotrophic counts are made after incubation of the plates at 22° C for seven days. The hydrocarbon-utilizing population was enumerated by spread plating dilutions of the soil samples on a mineral medium with toluene as the only carbon source. The mineral medium contained washed agar and essential inorganic nutrients. The hydrocarbon-utilizers were counted after 26 days incubation at 22° C.

4.2 MICROBIAL COUNT RESULTS

The heterotrophic microbial counts, presented in Table 3, remained relatively constant during the feasibility study at an average of 3.0×10^7 colony-forming units per gram (cfu/g) considering the samples collected at times 8, 15, 28, and 42. This average is an increase from the initial counts of 1.8×10^6 cfu/g analyzed at time 0. The initial samples included two samples each from both the top and bottom of the column. There were high numbers (2.8×10^6 cfu/g) of hydrocarbon-utilizing microbes in the initial samples. Although the hydrocarbon-utilizers indicated a decreasing trend throughout the duration of the test, the counts remained within the acceptable range.

4.3 MICROBIAL COUNT DISCUSSION

There were high counts of both heterotrophic and hydrocarbon-utilizing microbes in the initial soil samples indicating that conditions were favorable for microbial growth. These high counts are also an indication that the microbial population was acclimated to biodegrading the organic contaminants.

The numbers of microbes in these samples may actually be much greater than found by these enumeration procedures. Generally only 1 to 10 percent of the microorganisms in an environmental sample will be enumerated on agar media. The enumeration procedures may underestimate microbial numbers because many of the microorganisms are not able to utilize the substrates in the media, reproduce too slowly to form colonies in the incubation period, were not detached from the soil, or for other reasons do not grow on the agar medium. The size of the microbial community would be expected to increase with oxygen and nutrient additions from the operation of the bioremediation system.

5.0 IN SITU BIOVENTING TREATABILITY STUDY

5.1 IN SITU BIOVENTING STUDY INTRODUCTION

A biodegradation study was set up to simulate the field operations of in situ bioventing. An intact column was operated at a low vacuum and amended with nutrients and water to simulate bioventing conditions. At the end of the study, groundwater from site well RW-1 enriched with nutrients was passed through the soil column to determine if plugging might be encountered.

5.2 IN SITU BIOVENTING STUDY METHODS

A soil column was set up using the soil sample provided by GES. The soil core was 2.75 in (7 cm) in diameter and 36 inches (91 cm) long. The column was prepared for the bioventing study by removing one inch (2.54 cm) of soil from both the top and bottom of the core. The column contained approximately 7,000 g of soil based on the 3,500 cm³ of soil in the column and the density of 125 lb/ft³ (2.0 g/cm³). The soil removed from the top and bottom of the column was replaced with glass wool. A copper tube was inserted through the end cap and connected to a rubber stopper which was placed in 1 liter vacuum flasks. An adjustable vacuum source was used that had an air flow of 10 mL/min with a vacuum of 1 inch of water. An activated carbon trap (7.1 inch long by 0.6 inch diameter or 18 cm by 1.5 cm) containing 9.5 grams of carbon was placed between the column and the vacuum source to trap any volatiles that were removed during the bioventing process. The column was kept moist by passing air through a canister containing an aqueous solution of the nutrients (ammonia chloride and phosphate). The column was incubated at room temperature, approximately 22° C.

Samples were collected from the top of the column after 0, 8, 15, 28 and 42 days to be analyzed for BTEX by EPA Method 8020. Heterotrophic and hydrocarbon-utilizing bacteria were enumerated in samples from days -0-, 8, 15, 28, and 42. The percent moisture was determined at 0, 1, 2, 4, and 6 weeks by drying the soil in a 105° C oven overnight. All organic analyses have been corrected for percent moisture. The activated carbon traps were replaced after 15 and 42 days and analyzed for BTEX.

At the end of the bioventing study, groundwater enriched with nutrients was introduced onto the column to see what effects nutrient additions might have on the permeability of the soil. The groundwater, before introduction onto the column, was analyzed for pH, iron, and dissolved BTEX.

5.3 IN SITU BIOVENTING STUDY RESULTS

The volatile organic contaminants in the soil and activated carbon samples from the column study are presented in Tables 4 and 5 and Figure 1. Table 5 presents the mass balance for each volatile contaminant for the initial soil samples, the soil after treatment for six weeks,

and the activated carbon trap. The mass balances for the soil samples assumed a quantity of 7,000 g. Each trap had 9.5 g of activated carbon. Based upon the information in Table 5, it appeared that the Day -0- sample (refer to Table 4) from the studies was not representative of the overall contamination levels at the site because of the much higher levels of volatile contaminants on the activated carbon trap than the initial soil. Also, there was a much higher level of m,p-xylene in the Day 8 sample (700 ug/kg) than the Day -0- sample (39 ug/kg) which also suggested that the Day -0- samples were not representative. Because of the high level of m,p-xylene detected in the Day 8 sample, a dilution had to be run and none of the other contaminants were detected.

There was an overall decline in the concentrations of volatile organics in the soil from Day -0- to Day 42. Benzene was not detected in the soil, although it was found at concentrations of 48,000 and 21,000 ug/kg on the activated carbon traps. Based on analytical results from other soil samples at the site, it appears that the benzene detected in the activated carbon trap could have resulted from lab contamination. Toluene was reduced from 38 to 3.8 ug/kg in the soil samples, a reduction of 90%. Ethylbenzene, m,p-xylenes, and o-xylenes were also removed to below the detection limit of <0.5 ug/kg in the Day 42 samples.

The heterotrophic and hydrocarbon-utilizing microbial counts over the course of the study are given in Table 3. The heterotrophic counts increased from 1.8×10^6 cfu/g to 1.8×10^8 cfu/g between the initial sample and the sample collected at Day 8. The heterotrophic counts then declined to 2.7×10^7 on Day 42. Counts of hydrocarbon-utilizers declined from 2.8×10^6 cfu/g on Day -0- to 8.0×10^5 cfu/g on Day 28. Hydrocarbon-utilizer counts from Day 42 were not available when this report was prepared.

The moisture content of the soil declined from the initial 20.2 percent to 15.3 percent on Day 42. The decrease in moisture content of the soil would likely reduce microbial activity somewhat, although these soils were still moist enough to support microbial activity.

A groundwater sample collected from RW-1 was used to test the effects of nutrient additions on the soil. This sample contained 25 mg/L iron, 22 ug/L benzene, 52,000 ug/L toluene, 460 ug/L ethylbenzene, 1,200 ug/L m,p-xylenes, and 410 ug/L o-xylene, and had a pH of 6.7. The column plugged after one pore volume of water had passed through the soil.

5.4 IN SITU BIOVENTING STUDY DISCUSSION

The mass balances on the activated carbon samples suggested that the majority of the removal that occurred was likely a result of volatilization, rather than biodegradation. Anomalies experienced during this test, including higher than anticipated VOCs absorbed in the carbon trap and benzene detected in the carbon trap but not in the soil sample, can not be readily explained. As noted, benzene detected in the carbon trap may be the result of laboratory contamination. The excessive concentrations of other VOCs detected in the carbon trap (see Table 4) could be partially influenced by laboratory contamination. Also, it is possible that impact to the soils within the Shelby tube were restricted to a zone within the core of the sample. If this is the case, there is a chance that high VOC concentrations were not detected

during laboratory analysis since soil samples were always removed from the ends of the sample. Mass balance calculations show that much of the VOC removal from the sample occurred via volatilization. However, the two orders of magnitude increase in the numbers of heterotrophic bacteria during the first eight days of the study suggest that biodegradation played a role in the removal of the contaminants. However, the microbial counts declined as the volatile organic constituents and moisture content of the soil decreased.

Introduction of nutrients to the groundwater and circulation through the vadose zone is likely to lead to plugging problems because of the high iron content of the groundwater and the moderately high levels of silt and clay in the soil.

6.0 CONCLUSIONS

Although bioventing appears to be a viable remediation technique for this site, venting alone may be able to reduce the volatile aromatic concentrations to an acceptable level. We also do not recommend that traditional in situ bioremediation be used without additional feasibility tests. TSI reaches the following conclusions about this site:

- * The soil contains acceptable numbers of heterotrophic microbes with a substantial portion of hydrocarbon-utilizers.
- * It appeared that bioventing would be an effective treatment for these soils. There appears to be sufficient nutrients and moisture in the soil to support biodegradation of the contaminants during bioventing. The bioventing system could be operated with a high air flow rate to remove as much of the volatile contaminants as possible. After the levels of volatile contaminants in the air stream have fallen, the air flow rate in the system could be reduced and biodegradation promoted.
- * Introduction of nutrients to the groundwater and circulation through the vadose zone does not seem to be practical for this site.

TABLES

Table 1

Inorganic Nutrients in Quebecor Soil		
Compound	Units	MVTL
Nitrate-Nitrogen	ppm	2.6
Total Kjeldahl Nitrogen	mg/l	220
Phosphorus	ppm	5
Potassium	ppm	10
Zinc	ppm	0.5
Sulfate-Sulfur	ppm	26
pH		6.6
Calcium	ppm	800
Magnesium	ppm	150
Boron	ppm	0.2
Iron	ppm	67.2
Manganese	ppm	4.9
Copper	ppm	0.7
Sodium	ppm	13
CEC	ppm	5.3
Organic Matter	%	2.3
Salts	mmhos/cm	0.2
Texture		Med/Fine

Table 2

Particle Size Analysis	
Fraction	Percent
Gravel	9.45
Coarse Sand	4.16
Medium Sand	19.21
Fine Sand	54.32
Clay and Silt	13.41

TABLE 3		
MICROBIAL COUNTS		
Soil Sample Day	TOTAL COUNT NUTRIENT AGAR	HYDROCARBON UTILIZER MINERAL AGAR
0	1.8×10^6	2.8×10^6
8	1.8×10^8	2.5×10^6
15	2.4×10^7	1.2×10^6
28	3.9×10^7	8.0×10^5
42	2.7×10^7	No Data Available

Sample Description: Bioventing Feasibility Study -- Quebecor, Inc.

TABLE 4					
BTEX CONCENTRATIONS					
Soil (ug/kg*)					
COMPOUND	TIME				
	DAY 0	DAY 8	DAY 15	DAY 28	DAY 42
Benzene	< 0.6	<300	<0.5	<0.6	<0.5
Toluene	38	<300	5.3	6.2	3.8
Ethyl Benzene	18	<300	<0.5	<0.6	<0.5
Meta & Para-Xylene	39	700	2.9	4.3	<0.5
Ortho-Xylene	7.5	<300	7.8	4.0	<0.5
Activated Carbon (ug/kg*)					
COMPOUND	TIME				
	DAY 0	DAY 8	DAY 15	DAY 28	DAY 42
Benzene**			48000		21000
Toluene			1100000		260000
Ethyl Benzene			23000		53000
Meta & Para-Xylene			27000		7300
Ortho-Xylene			<13000		<5000

* Dry Weight Basis

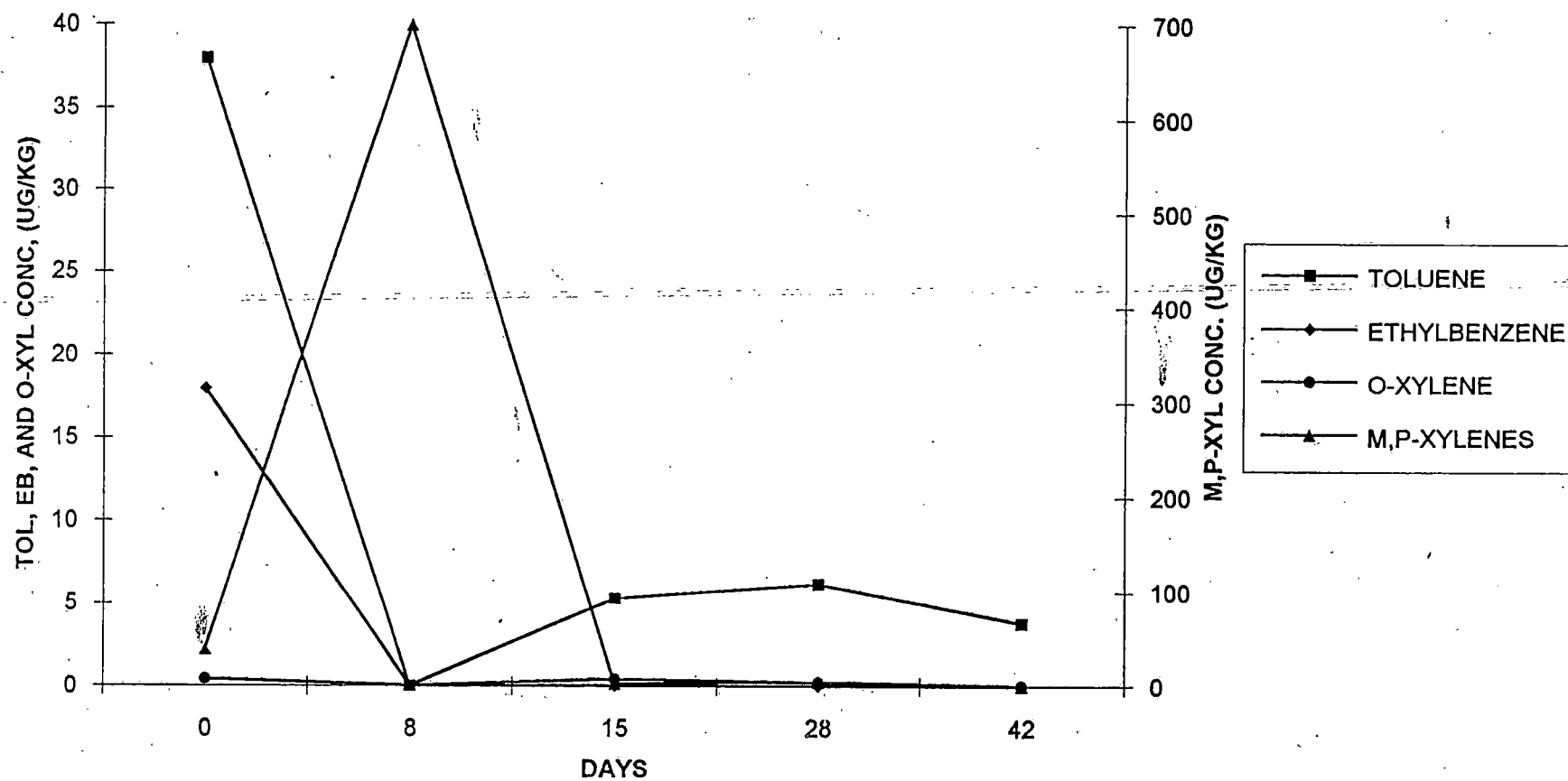
** Please refer to Section 5.3 & 5.4

TABLE 5**ESTIMATED QUANTITY OF VOLATILE ORGANIC CONTAMINANTS DURING
BIODEGRADATION STUDIES**

COMPOUND	SOIL (ug)	SOIL RESIDUAL (ug)	CARBON TRAP (ug)
Benzene	<4.2	<3.5	656
Toluene	266	26.6	12920
Ethyl Benzene	126	<3.5	269
Meta & Para-Xylene	273	<3.5	326
Ortho-Xylene	52	<3.5	<171

FIGURES

VOLATILE ORGANIC CONTAMINANTS
QUEBECOR--ATGLEN
BIOVENTING STUDY



APPENDIX A

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 67302B
MATRIX : SOIL
CLIENT ID : Quebecor Time 0

DATE ANALYZED : 06/02/1994
DATE RECVD : 05/23/1994

DATA FILE : BTX12006
SAMPLE wt/vol: 5.00 gm
Percent Moisture : 20.2

COMPOUND

RESULT
(ug/kg*)

Detection
Limit (ug/kg*)

71-43-2 Benzene
108-88-3 Toluene
100-41-4 Ethyl Benzene
106-42-3 Meta & Para-Xylene
95-47-6 Ortho-Xylene

ND
38
18
39
7.5

0.6
0.6
0.6
0.6
0.6

ND Not Detected
B Analyte Also found in blank
D Diluted
E Estimated

Dry Weight Basis
e15/btx.id/1.253

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 67650
MATRIX : SOIL
CLIENT ID : Biovent-Day 8

DATE ANALYZED : 06/02/1994
DATE RECVD : 05/31/1994

DATA FILE : BTX12012
SAMPLE wt/vol: 0.01 gm
Percent Moisture : 16.2

COMPOUND		RESULT (ug/kg*)	Detection Limit (ug/kg*)
71-43-2	Benzene	ND	300
108-88-3	Toluene	ND	300
100-41-4	Ethyl Benzene	ND	300
106-42-3	Meta & Para-Xylene	700	300
95-47-6	Ortho-Xylene	ND	300
ND Not Detected			
B Analyte Also found in blank			
D Diluted			
E Estimated			

Dry Weight Basis
File21/btx.id/596.659

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTX GC/PID)

LAB SAMPLE # : 68053
MATRIX : SOIL
CLIENT ID : Biovent-Day 15

DATE ANALYZED : 06/14/1994
DATE RECVD : 06/07/1994

DATA FILE : BTX17014
SAMPLE wt/vol: 5.00 gm
Percent Moisture : Not Found

COMPOUND	RESULT (ug/kg*)	Detection Limit (ug/kg*)
71-43-2 Benzene	ND	0.5
108-88-3 Toluene	5.3	0.5
100-41-4 Ethyl Benzene	ND	0.5
106-42-3 Meta & Para-Xylene	2.9	0.5
95-47-6 Ortho-Xylene	7.8	0.5

ND Not Detected
B Analyte Also found in blank
D Diluted
E Estimated

Dry Weight Basis
file14/btx.id/1.000

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 68364
MATRIX : SOIL
CLIENT ID : Quebecor-Day 28

DATE ANALYZED : 06/27/1994
DATE RECVD : 06/13/1994

DATA FILE : BTX24013
SAMPLE wt/vol: 5.00 gm
Percent Moisture : 16.6

COMPOUND	RESULT (ug/kg*)	Detection Limit (ug/kg*)
71-43-2 Benzene	ND	0.6
108-88-3 Toluene	6.2	0.6
100-41-4 Ethyl Benzene	ND	0.6
106-42-3 Meta & Para-Xylene	4.3	0.6
95-47-6 Ortho-Xylene	4.0	0.6

ND Not Detected
B Analyte Also found in blank
D Diluted
E Estimated

Dry Weight Basis
file13/btx.id/1.199

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 69167
MATRIX : SOIL
CLIENT ID : Quebecor Day 42

DATE ANALYZED : 06/29/1994
DATE RECVD : 06/27/1994

DATA FILE : BTX26011
SAMPLE wt/vol: 5.00 gm
Percent Moisture : Not Found

COMPOUND		RESULT (ug/kg*)	Detection Limit (ug/kg*)
71-43-2	Benzene	ND	0.5
108-88-3	Toluene	3.8	0.5
100-41-4	Ethyl Benzene	ND	0.5
106-42-3	Meta & Para-Xylene	ND	0.5
95-47-6	Ortho-Xylene	ND	0.5
ND Not Detected			
B Analyte Also found in blank			
D Diluted			
E Estimated			

* Dry Weight Basis
all/btx.id/1.000

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 68054
MATRIX : SOIL
CLIENT ID : Carbon-Day 15

DATE ANALYZED : 06/16/1994
DATE RECVD : 06/07/1994

DATA FILE : BTX19015
SAMPLE wt/vol: 0.00 gm
Percent Moisture : Not Found

COMPOUND

RESULT
(ug/kg*)

Detection
Limit (ug/kg*)

71-43-2 Benzene
108-88-3 Toluene
100-41-4 Ethyl Benzene
106-42-3 Meta & Para-Xylene
95-47-6 Ortho-Xylene

48000
1100000
23000
27000
ND

13000
13000
13000
13000
13000

ND Not Detected
B Analyte Also found in blank
D Diluted
E Estimated

Dry Weight Basis
ie15/btx.id/25000.000

18615

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 69168
MATRIX : SOIL
CLIENT ID : Quebecor Carbon

DATE ANALYZED : 06/29/1994
DATE RECVD : 06/27/1994

DATA FILE : BTX26012
SAMPLE wt/vol: 0.0005 gm
Percent Moisture : Not Found

COMPOUND	RESULT (ug/kg*)	Detection Limit (ug/kg*)
71-43-2 Benzene	21000	5000
108-88-3 Toluene	260000	5000
100-41-4 Ethyl Benzene	5300	5000
106-42-3 Meta & Para-Xylene	7300	5000
95-47-6 Ortho-Xylene	ND	5000

ND Not Detected
B Analyte Also found in blank
D Diluted
E Estimated

Dry Weight Basis
e12/btx.id/10000.000

VOLATILE ORGANICS ANALYSIS DATA SHEET
(BTEX GC/PID)

LAB SAMPLE # : 69166D
MATRIX : WATER
CLIENT ID : RW-1 Influent

DATE ANALYZED : 06/29/1994
DATE RECVD : 06/27/1994

DATA FILE : BTX26013
SAMPLE wt/vol: 0.50 ml

COMPOUND	RESULT (ug/L)	Detection Limit (ug/L)
71-43-2 Benzene	22	5.0
108-88-3 Toluene	52000 D	5.0
100-41-4 Ethyl Benzene	460	5.0
106-42-3 Meta & Para-Xylene	1200 D	5.0
95-47-6 Ortho-Xylene	410 D	5.0

ND Not Detected
B Analyte Also found in blank
D Diluted
E Estimated

file13/btx.id/10.000



LABORATORIES, Inc.

SOIL TEST REPORT



NEW ULM, MN PH. 507-354-8517

NEVADA, IA PH. 515-382-5486

GRAND FORKS, ND PH. 701-746-8335

COMMITTED BY: 23995 TERRA SYSTEMS INC DICK RAYMOND - SUITE E 1035 PHILADELPHIA PIKE WILMINGTON, DE 19809-2039	DATE RECEIVED: 05-25-94 DATE REPORTED: 05-27-94 WORK ORDER NO: 11-0712 LAB NOS: 1009-930	SUBMITTED FOR: QUEBECOR
--	---	---------------------------------------

V8.23 940426	SAMPLE ID	TIME 0	PREV. CROP	SAMPLE ID	PREV. CROP																																										
		V - LOW	LOW	MED	HIGH	V - HIGH		V - LOW	LOW	MED	HIGH	V - HIGH																																			
ORGANIC MATTER	2.3%																																														
NITROGEN (NO ₃ -N) LBS/A	5	(0-6") 2.6 ppm																																													
PHOSPHORUS (P) PPM	5																																														
POTASSIUM (K) PPM	10																																														
ZINC ppm	.5																																														
SULFUR (SO ₄ -S) ppm	26.0																																														
ACIDITY pH	6.6	B ppm	Fe ppm	Mn ppm	Cu ppm	Na ppm	B ppm	Fe ppm	Mn ppm	Cu ppm	Na ppm																																				
BUFFER INDEX		.2(L)	67.2(S)	4.9(S)	.7(S)	13																																									
		SALTS mmhos/cm .2					TEXTURE MED/FINE					SALTS mmhos/cm					TEXTURE																														
CALCIUM PPM	800.0	CEC	Ca	Mg	% BASE SATURATION	K	Na	H	CEC	Ca	Mg	% BASE SATURATION	K	Na	H																																
MAGNESIUM PPM	150	5.3	75.2	23.2	.5	1.1																																									
ALL RECOMMENDATIONS ARE ON A BROADCAST BASIS																CROP FERTILIZER RECOMMENDATIONS																CROP FERTILIZER RECOMMENDATIONS															
CROP AND YIELD GOAL		---				---				ACTUAL																																					
NITROGEN (lbs/A)																																															
STANDARD P ₂ O ₅ (lbs/A)																																															
BUILD (B) OR CROP REMOVAL (CR)																																															
STANDARD K ₂ O (lbs/A)																																															
BUILD (B) OR CROP REMOVAL (CR)																																															
ZINC (lbs/A)																																															
SULFUR (lbs/A)																																															
LIME NEEDS to pH 6.0 AS 100% ECCE (lbs/acre) to pH 6.5		No lime required.																																													

ADDITIONAL RECOMMENDATIONS AND COMMENTS:

- 1) There is a possibility of BORON deficiency. This should be confirmed by plant analysis before application.
- 2) Refer to reverse side for explanation of soil tests and fertilizer recommendations.

1.0

Raytheon
Engineers & Constructors
301 CHELSEA PARKWAY
BOOTHWYN, PA 19061
(215) 497-8000
(FAX -8005)

LABORATORY JOB NO.: 7575 304

SAMPLERS: L.O. SHEA

SEND INVOICE TO:

PHONE:

FAX:

REPORT NEEDED BY:

REPORT TYPE: TIER I ☐ TIER II ☐ STANDARD ☒ QC ☐ OTHER ☐

FOR LAB USE ONLY:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

P.O. NO.:

DUPLICATE DATE:

COOLER SEAL

YES.....NO.....

BROKEN. . . . INTACT. . . .

COOLER TEMP.: deg. F

ANALYSIS REQUIRED

PH 460
EC 33-
10/11/11 p
VOR - TEN 315 -
6278

QUOTE NO

SUMMARY NO.

18878

LABORATORY NO.

69166A

69166B

691660

691660

69167

6968

RELINQUISHED BY

RECEIVED BY

METHOD OF SHIPMENT

NAME:
OF:

DATE: _____
TIME: _____

NAME:
OF:

DATE: 11/11/1964

NAME:
OF:

DATE:
TIME:

NAME: _____
 OF: _____

DATE: 11-1-68

NAME: _____
OF: _____

DATE: _____
TIME: _____

NAME: _____
OF: _____

DATE: _____

AIRBILL NO.:

33

CHAIN OF CUSTODY RECORD

[illegible]

RE&C ENVIRONMENTAL LABORATORY

PARTICLE SIZE ANALYSIS OF SOILS (AP-Z08/ASTM D422)

Sieve Analysis Only

Client: Terra Systems

Project: Quebecor

Job No. : 7575304

Location:

Tested By: LEO

Checked By:

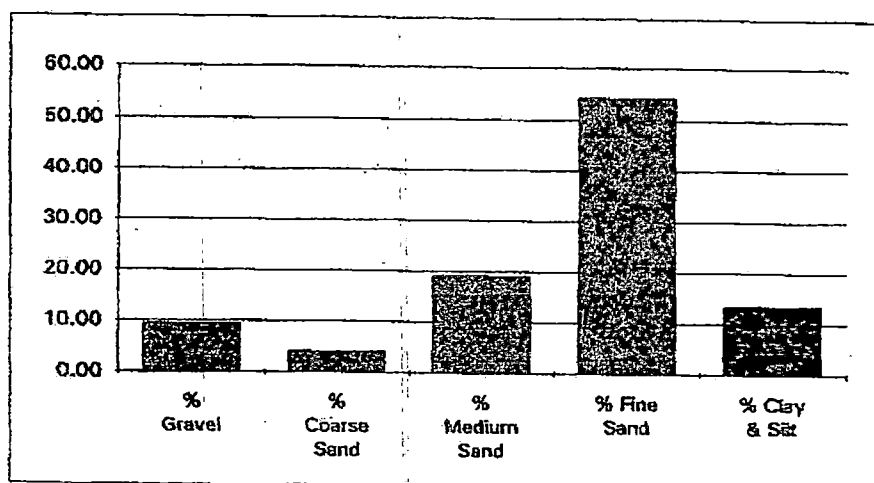
Lab Sample Log Number: 67302A

Time 0

Method of Test: ASTM-D422

Date: 06/30/94

% Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Clay & Silt
9.45	4.16	19.21	54.32	13.41



APPENDIX E
SUMMARY OF ENGINEERING PRACTICES AND EQUIPMENT
DESIGNS UTILIZED TO PROHIBIT FUTURE RELEASES



QUEBECOR PRINTING
ATGLEN INC.

August 5, 1994

G.E.S., Inc.
410 Eagleview Blvd.
Exton, PA 19341

ATTN: SHARON ROBERTS

The following is a brief summary of items incorporated in the construction of our Aboveground Tank Farm to further reduce spill prevention at our facility.

Mechanical Requirements:

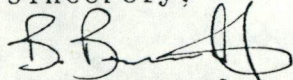
1. Pipe/Pipe Fittings - All pipe runs from Area "A" to Area "B" are A53 seamless pipe solid weld construction. All weld connections are in compliance with ANSI B31.1. All joints are leakproof and tested in accordance with the design pressure specified. All pipe tested with air at pressure of 200 PSIG at min. 8 hrs.
2. Flanges and Gasketing - All other connections are flange connected using a Gortex gasket. The gortex gasket replaces the Spiral-wound Monel due to better sealing abilities and resistance to solvent.
3. Valving - Special valving is being used on 1.5" seamless pipe.
SP40C1 - Ball Valve with spring return / fail-closed handle.
SP40C2 - Fire Safety Valve with heat actuated thermal trip and positive shutoff.
4. Load/Unload Pad - Concrete containment pad has been installed for all importing and exporting of solvents, inks and fuel oil. All pipe and meter racks are mounted in contained area. All connections for importing and exporting will be made in the contained area.
5. Aboveground Storage Tanks - Tanks for toluene, lacolene and xylene are double-wall UL 58 Type 1, 360-degree wrap. Interstitial monitoring from a tube extending to the top of the tank from a sump at the tank bottom. Tank fill connection provided with a 7 gallon overfill sump. Tanks inspected and leak tested in accordance with UL-142.

Electrical Requirements:

1. Interstitial monitoring of all tanks.
2. Multi-point level detection.
3. Electronic comparing of level detection and inventory level to constantly check the volume in the tank.
4. Electronic pump running / flow rate comparison to insure solvent is moving through the pipe system.
5. Automatic shutdown in the event of various system alarm conditions which could cause a problem or cause a situation which is out of the ordinary.
6. Automatic valve closure and pump shutdown should the computer/PLC Controller fail.
7. Wet detection at pump house Area "B" should there be leak or pump failure.
8. Emergency Shutdown push-buttons strategically located for manual shutdown by the operator.

Any other questions or concerns, please feel free to call.

Sincerely,



Bill Boerstler
PROJECT ENG.

cc: G. Adams
D. Potts